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Sub-Micrometre Resolution Transverse Electron Beam Size Diagnostics Using Spatial Properties of OTR Point Spread Function

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OUTLINE

- Introduction
- Experimental setup
- Calibration
- Quad Scan
- Window size
- Summary

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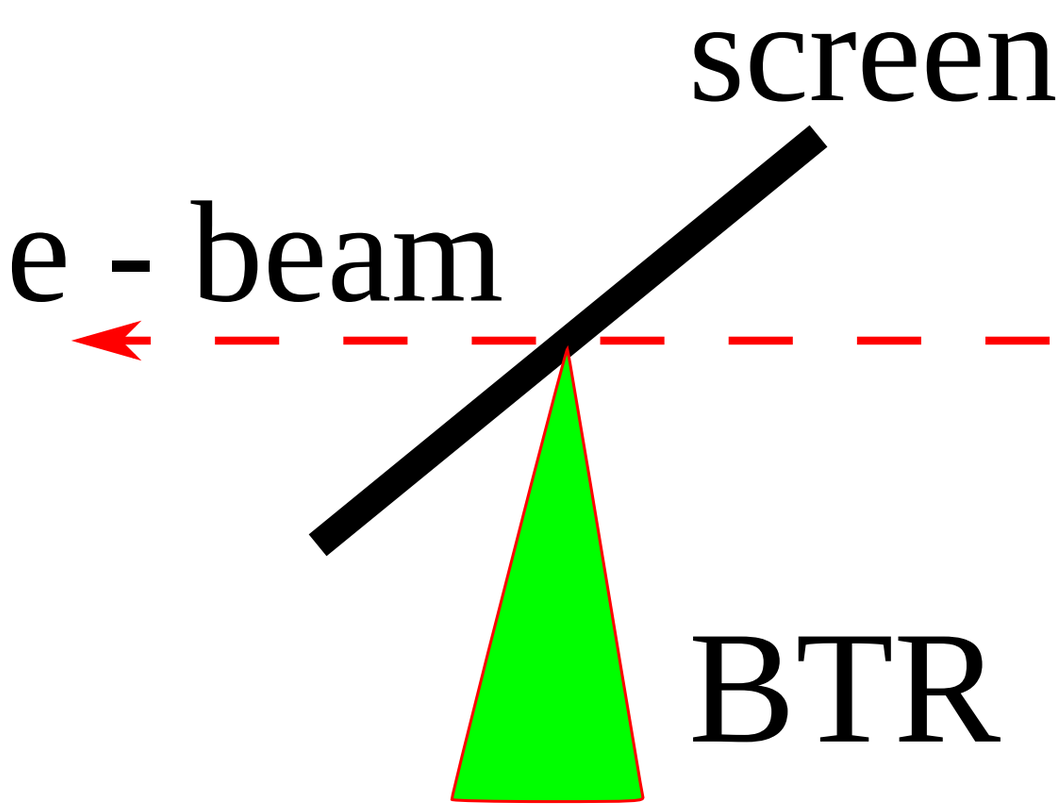
OTR



Transition radiation (TR) appears when a charged particle crosses a boundary between two media with different dielectric constants.

The resolution is determined by the source dimensions induced by a single particle plus distortion caused by the optical system (diffraction of OTR tails)

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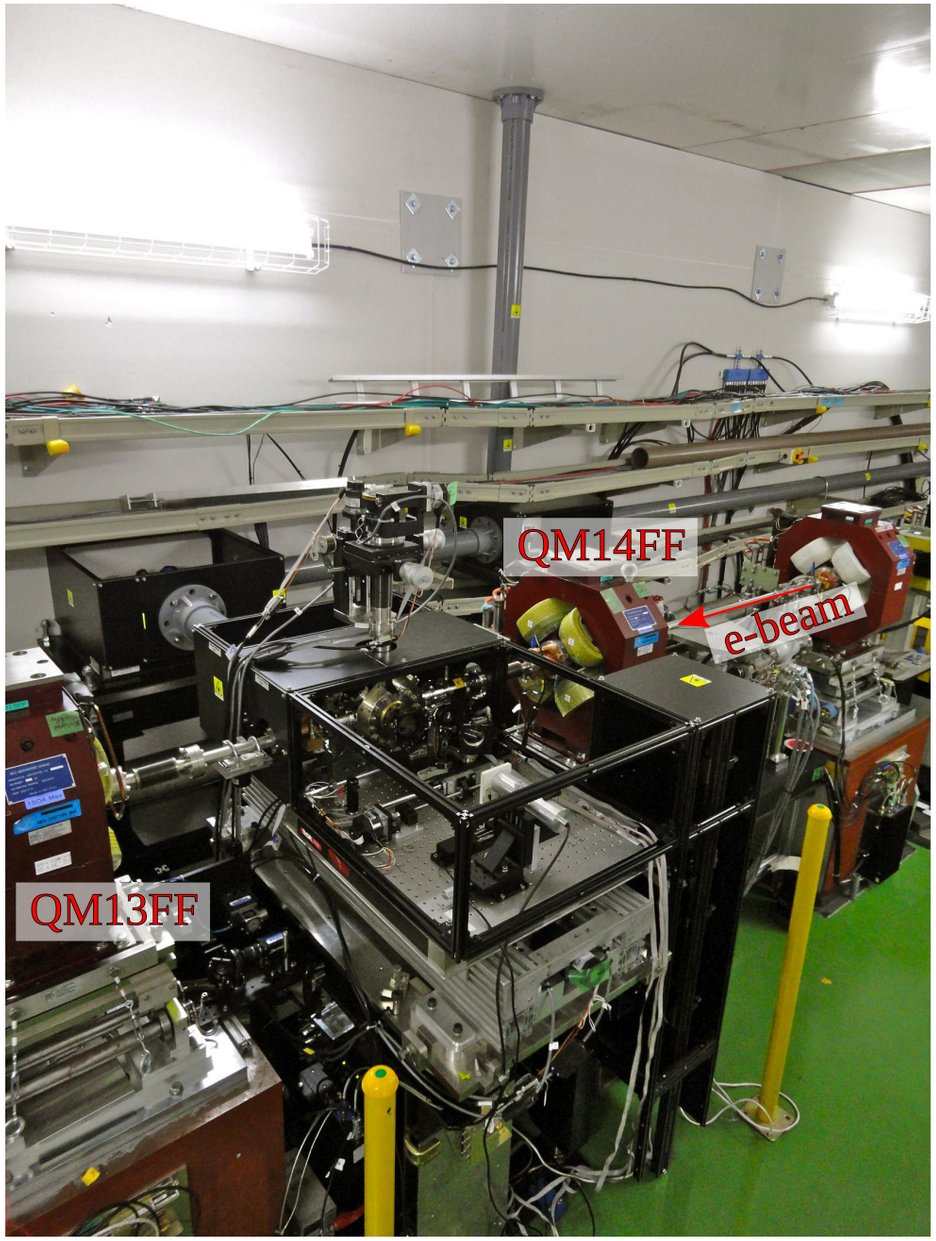
ATF2 EXTRACTION LINE



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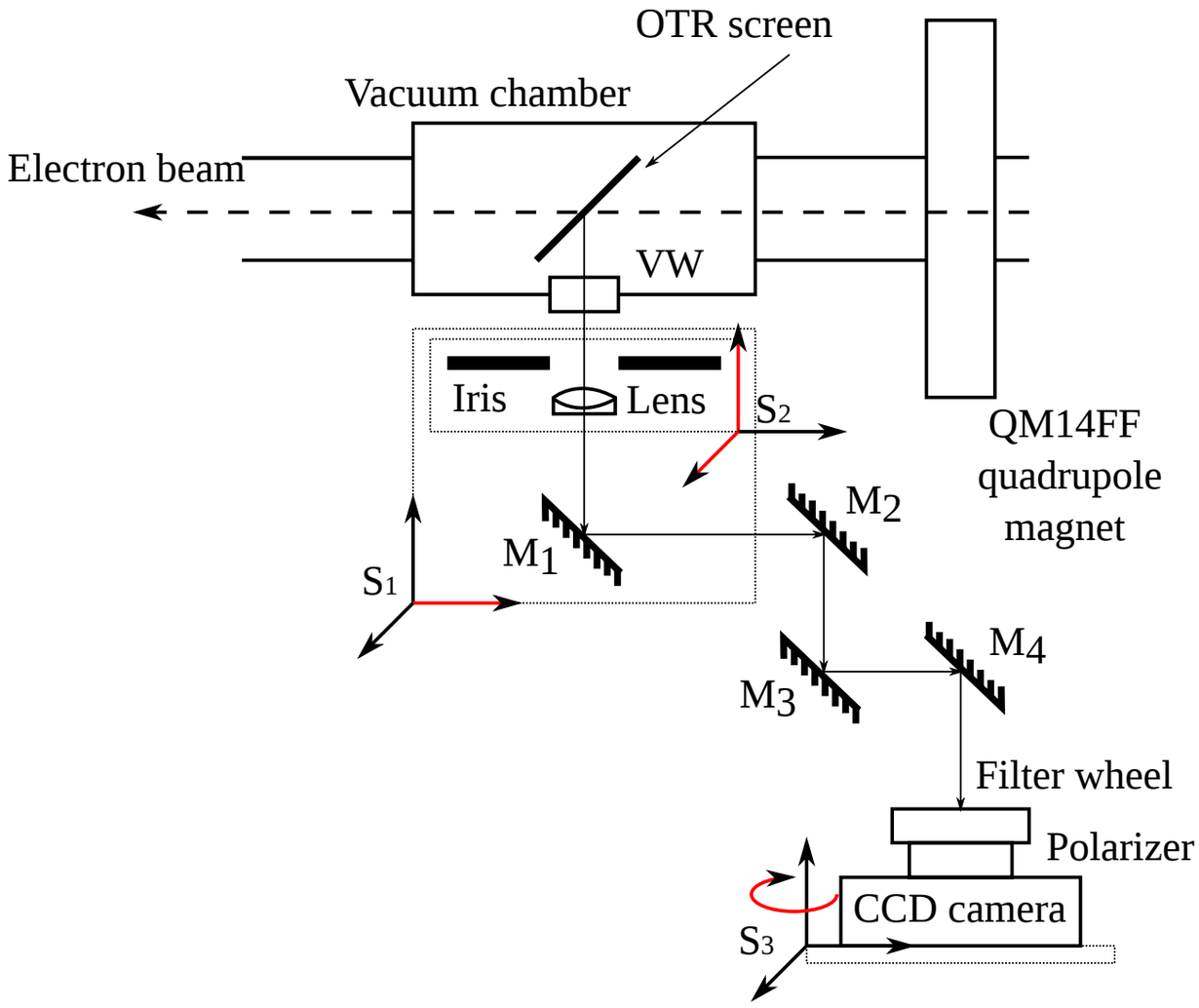
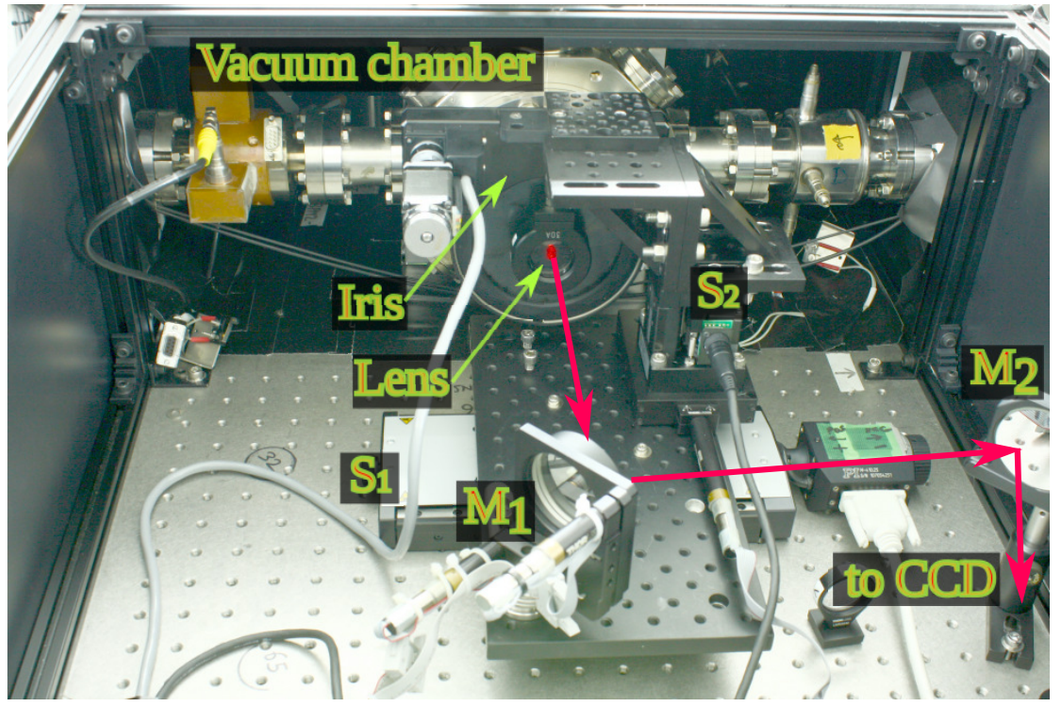
EXPERIMENTAL SETUP





CCD Camera - SBIG-ST8300M with 5.4 µm pixel size, 3352×2532 pixel array and ~50% quantum efficiency

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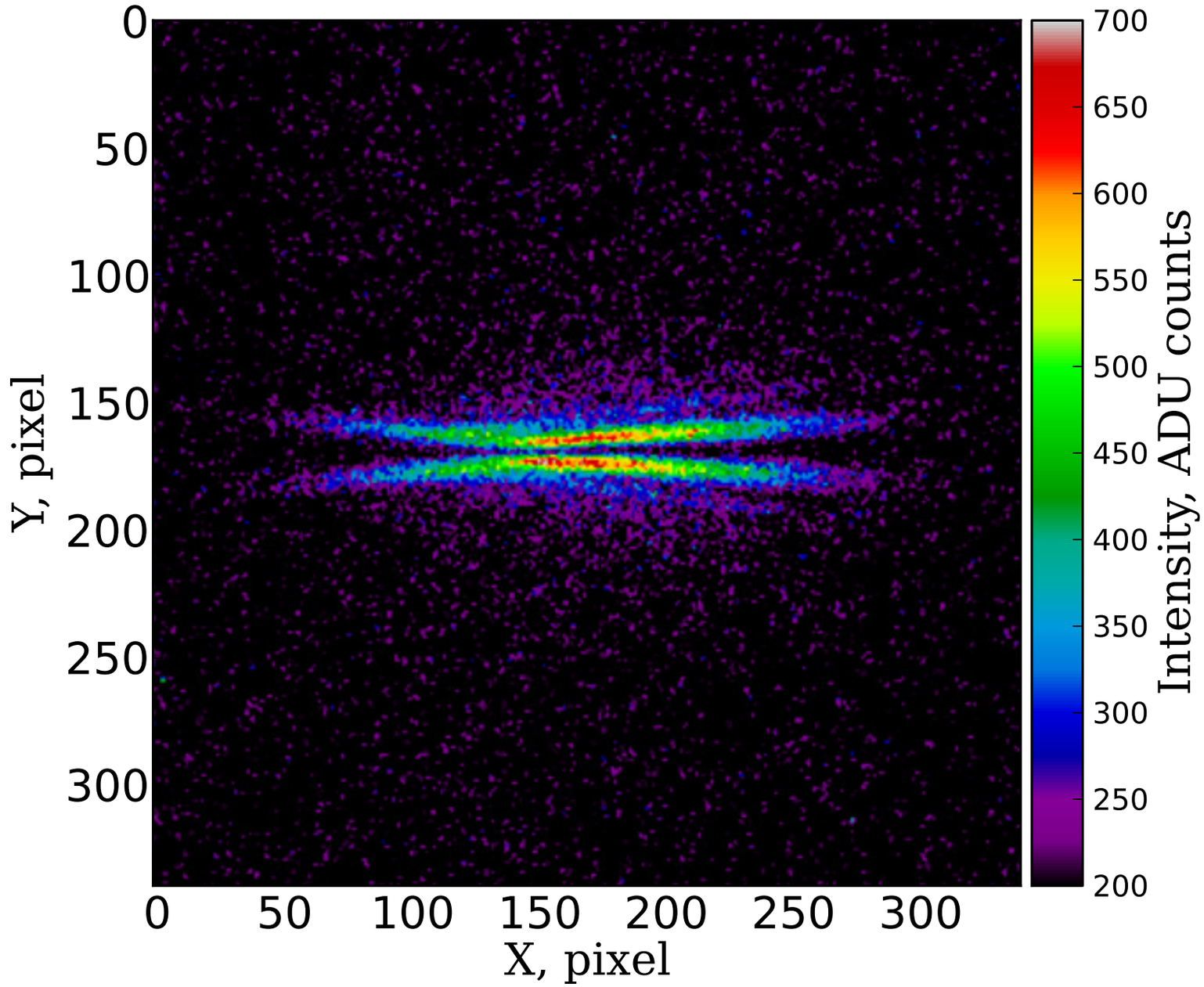
OTR IMAGE



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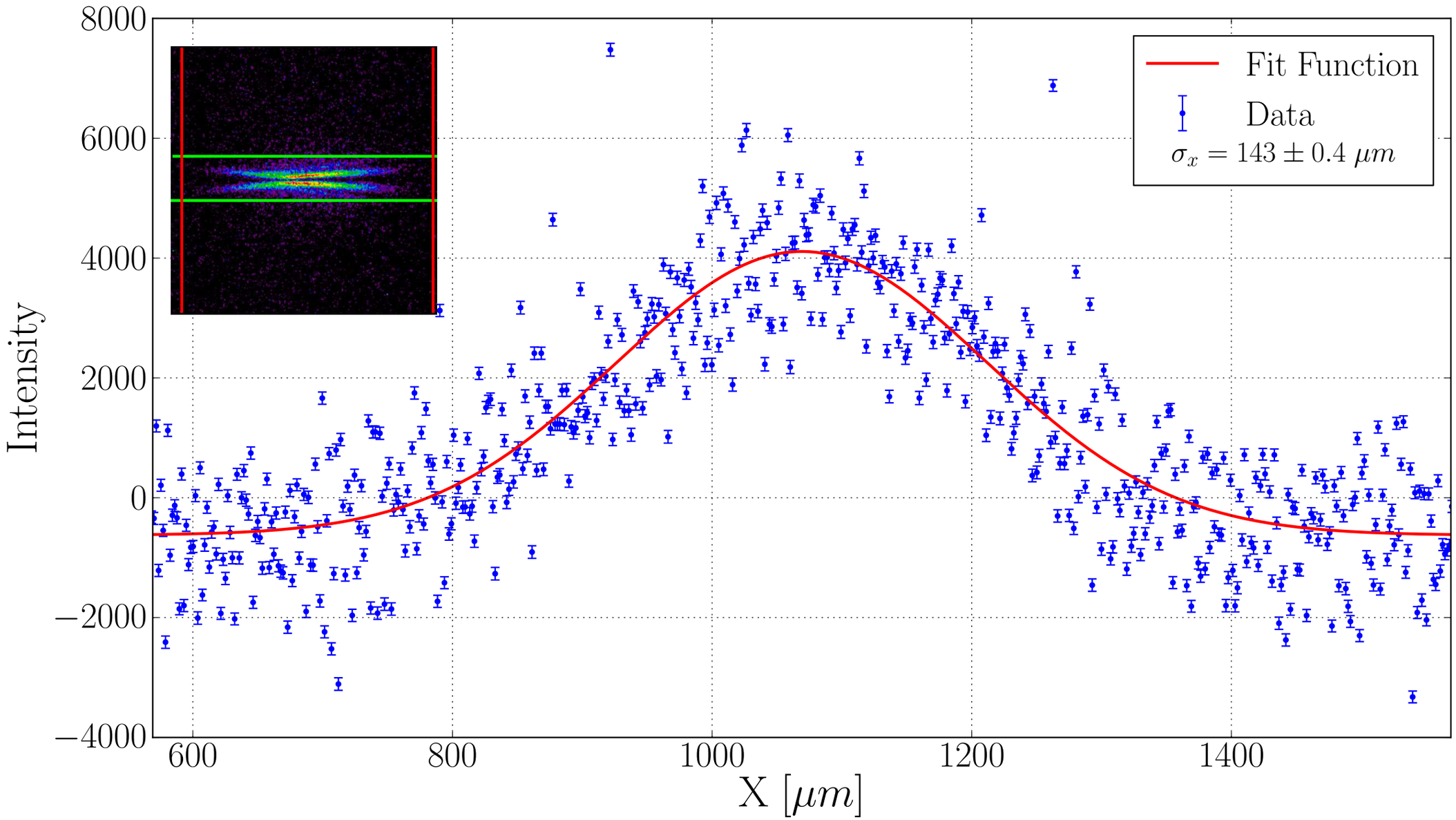
HORIZONTAL PROJECTION



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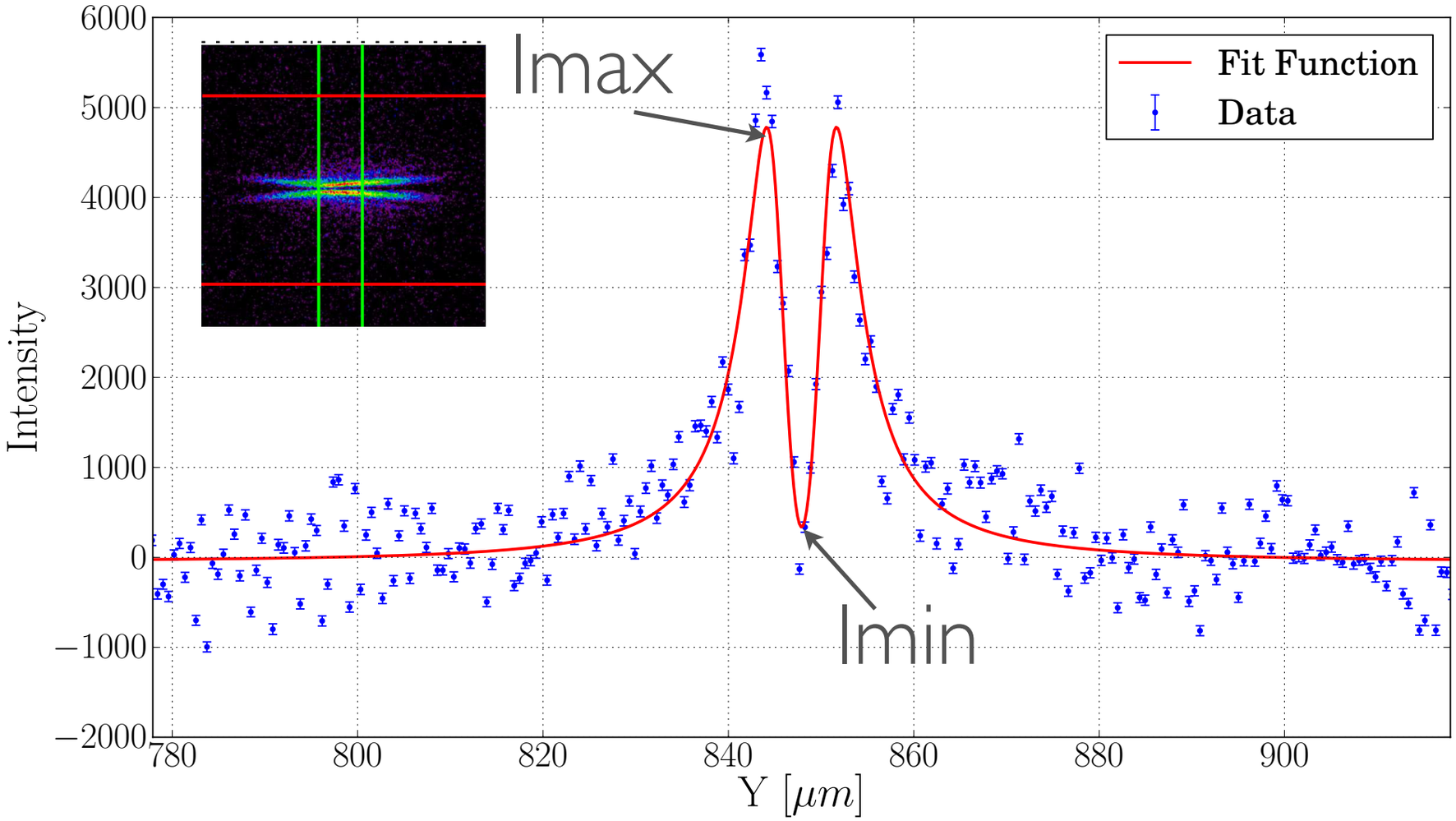
VERTICAL PROJECTION



- a_0 is the vertical offset of the distribution with respect to zero
- a_1 is the amplitude of the distribution
- a_2 is the smoothing parameter
- a_3 is the horizontal offset of the distribution with respect to zero
- a_4 is the distribution width

$$f(x) = a_0 + \frac{a_1\left(a_4 + (x - a_3)^2\right)}{1 + \left(a_2(x - a_3)\right)^4}$$

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PSF-LIKE FIT FUNCTION

Contrast ratio

$$\frac{I_{\min}}{I_{\max}} = \frac{2a_2^2 a_4}{a_2^2 a_4 + \sqrt{1 + a_2^4 a_4^2}}$$

Distance between peaks

$$\frac{2\sqrt{-a_2^2 a_4 + \sqrt{1 + a_2^4 a_4^2}}}{a_2}$$

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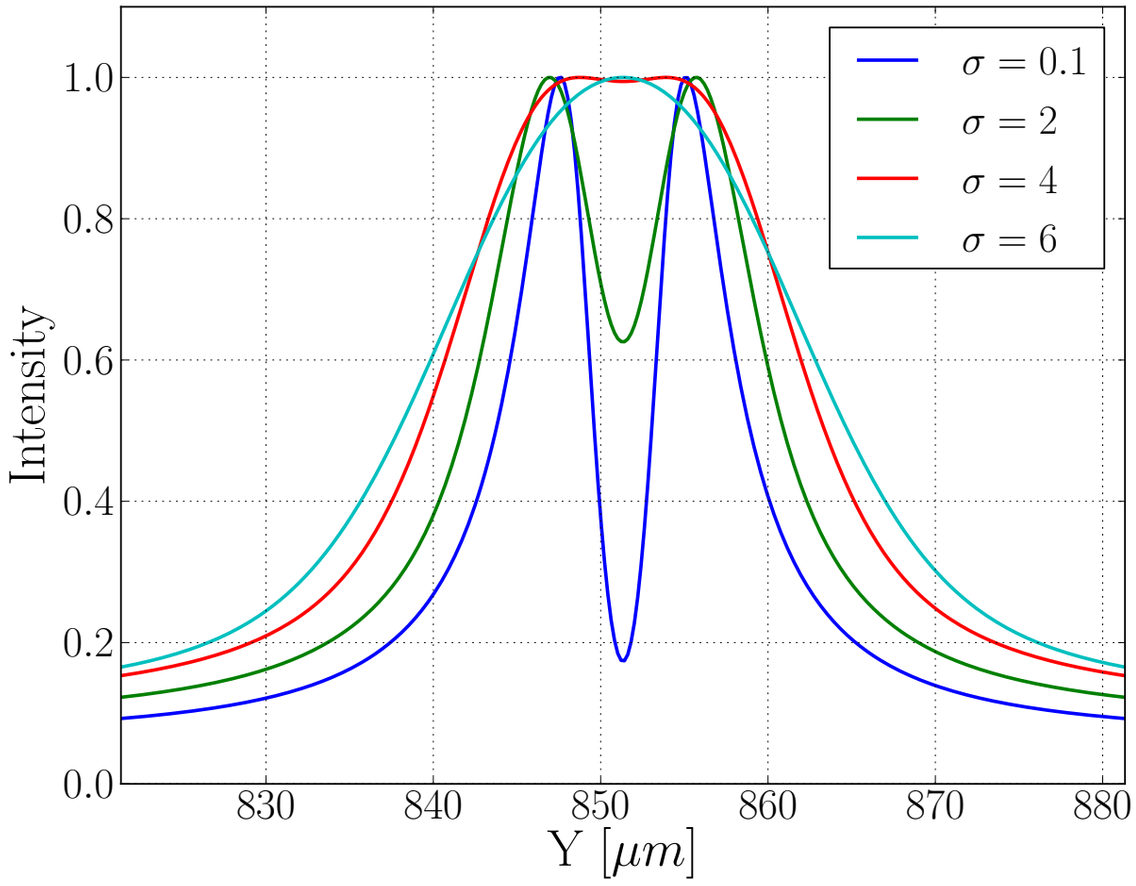
SELF-CALIBRATION



In the whole data set find a file with smallest Imin/Imax

Regenerate fit curve f(x) with errors for the calibration file substituting zeros a_0 and a_4

Convolute fit with Gaussian distribution as follows

$$F(x_j) = \frac{\sum_{i=1}^{N} f(x_i) \exp\left(\frac{-(x_j - x_i)^2}{2\sigma^2}\right)}{\sum_{i=1}^{N} \exp\left(\frac{-(x_j - x_i)^2}{2\sigma^2}\right)}$$

Propagate errors through convolution.

Repeat convolution N times varying σ from 0 to σm with a fine step.

For each iteration. find Imin/Imax and calculate its errors resulting in calibration curve

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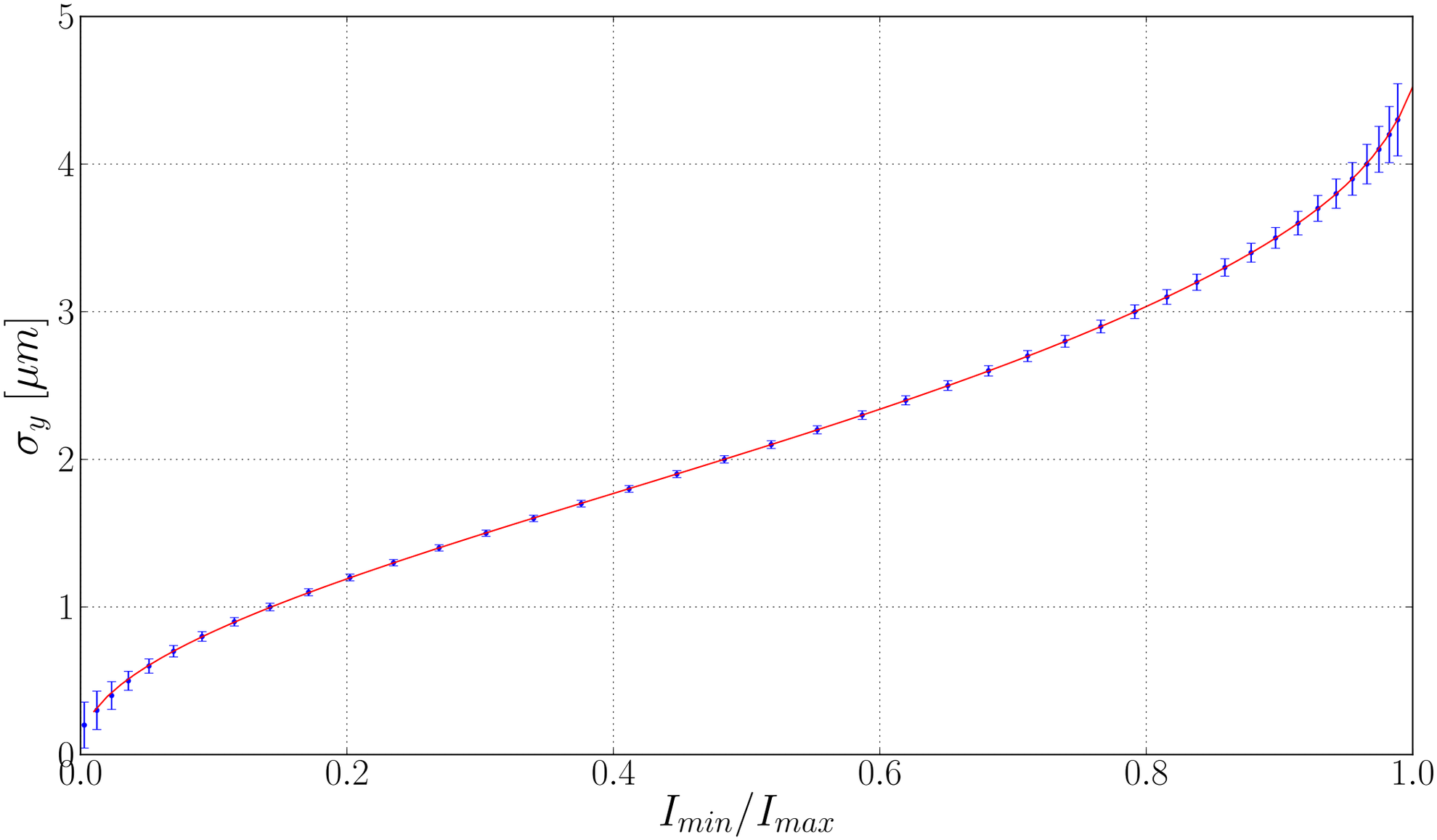
SELF-CALIBRATION



$$f(x) = a_0 + \frac{1}{a_1}\left(-\ln\left(1 - \frac{x}{a_2}\right)\right)^{a_3} + a_4 x^{12}$$

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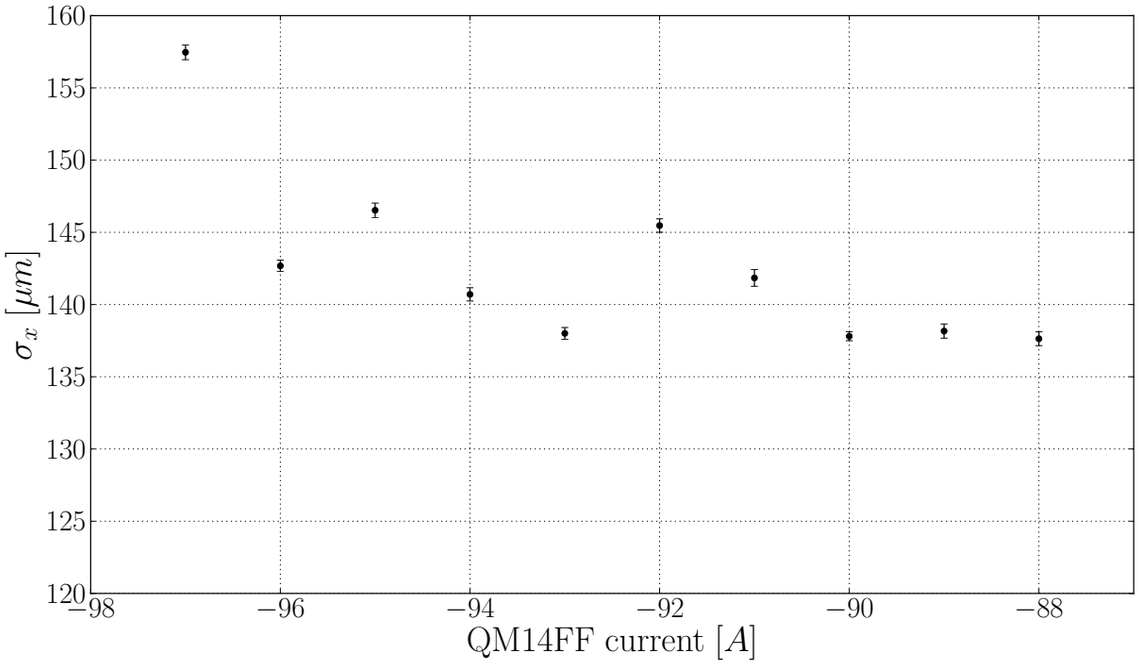
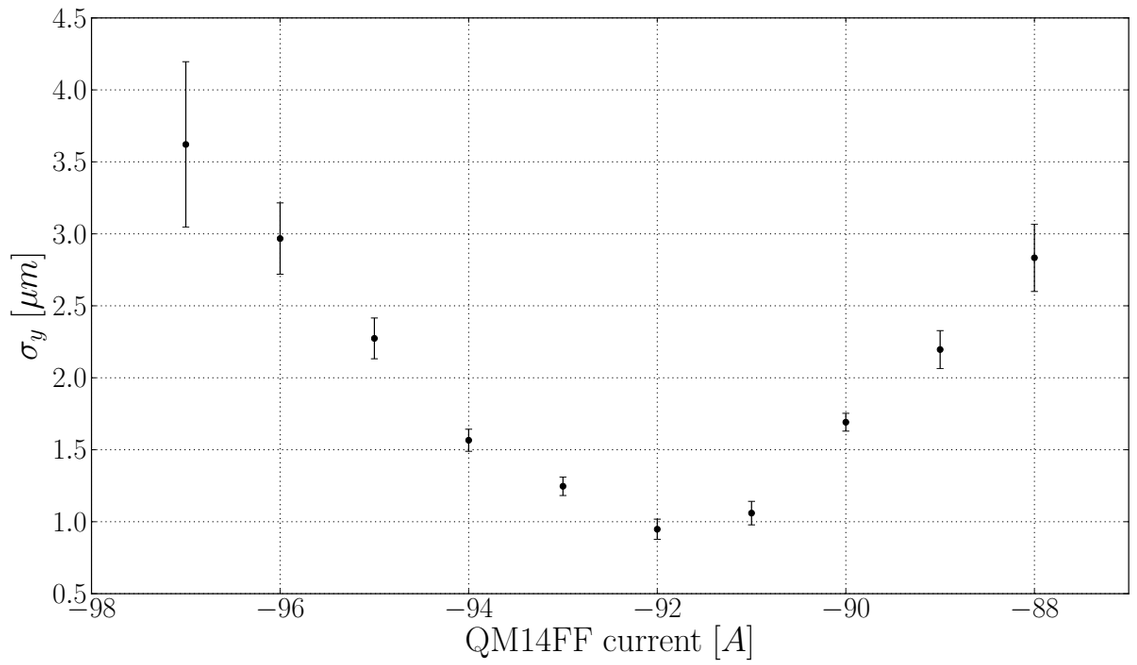
QUAD SCAN





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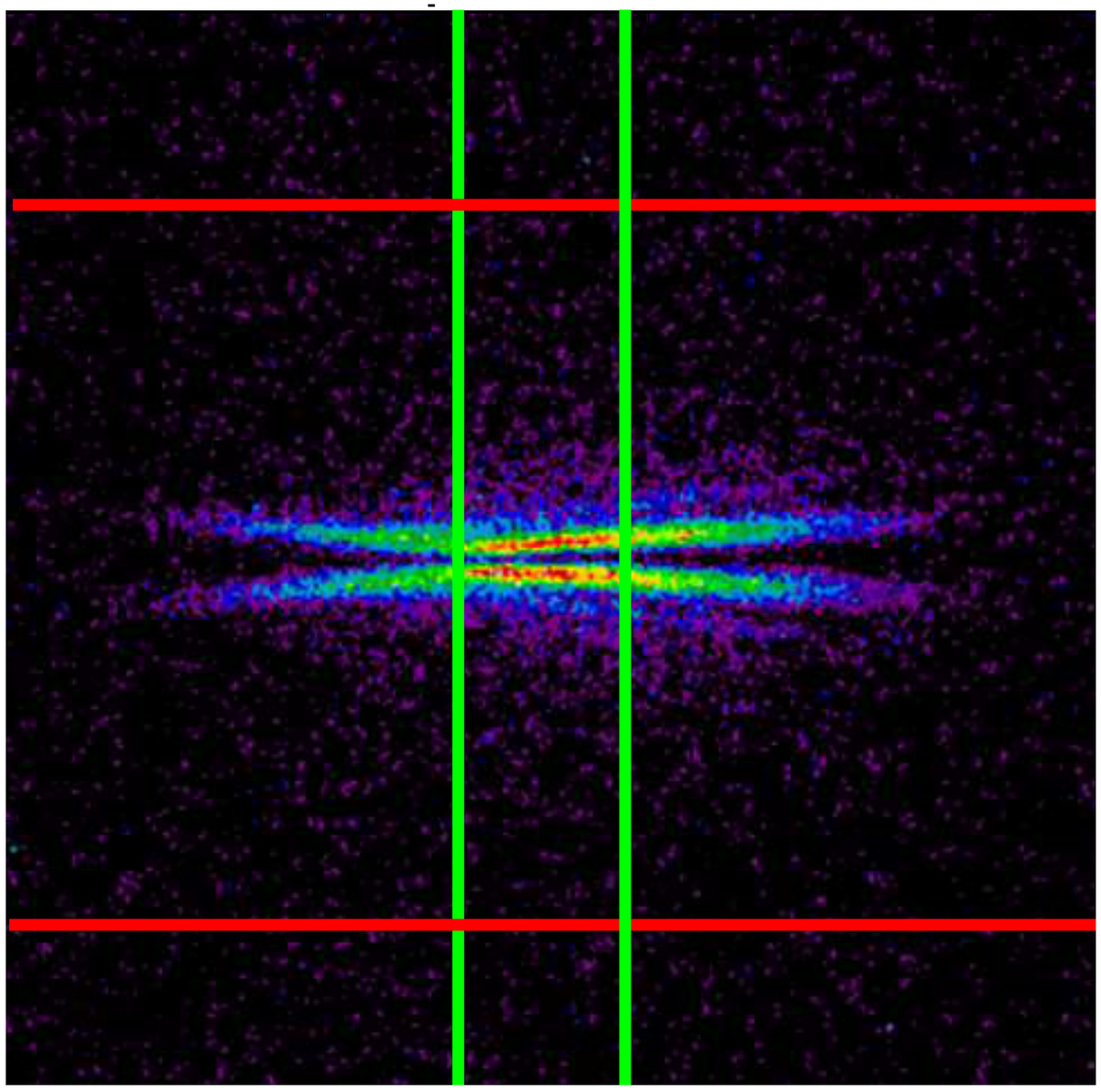
GAP SIZE



Gap

The choice of gap size affects the contrast ratio and beam size

- too small leads to large error
- too big systematically adds more noise

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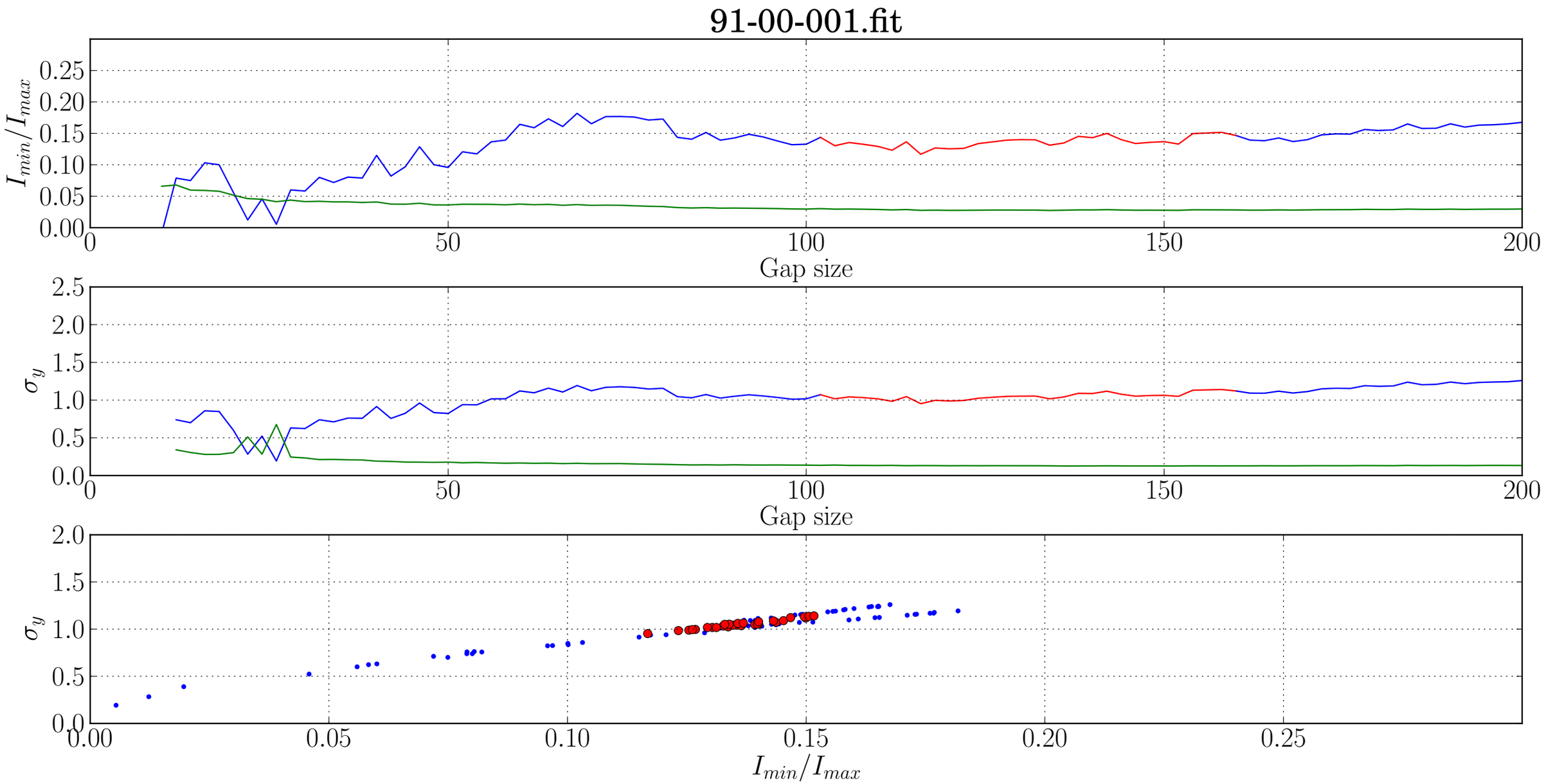
CURSOR SIZE



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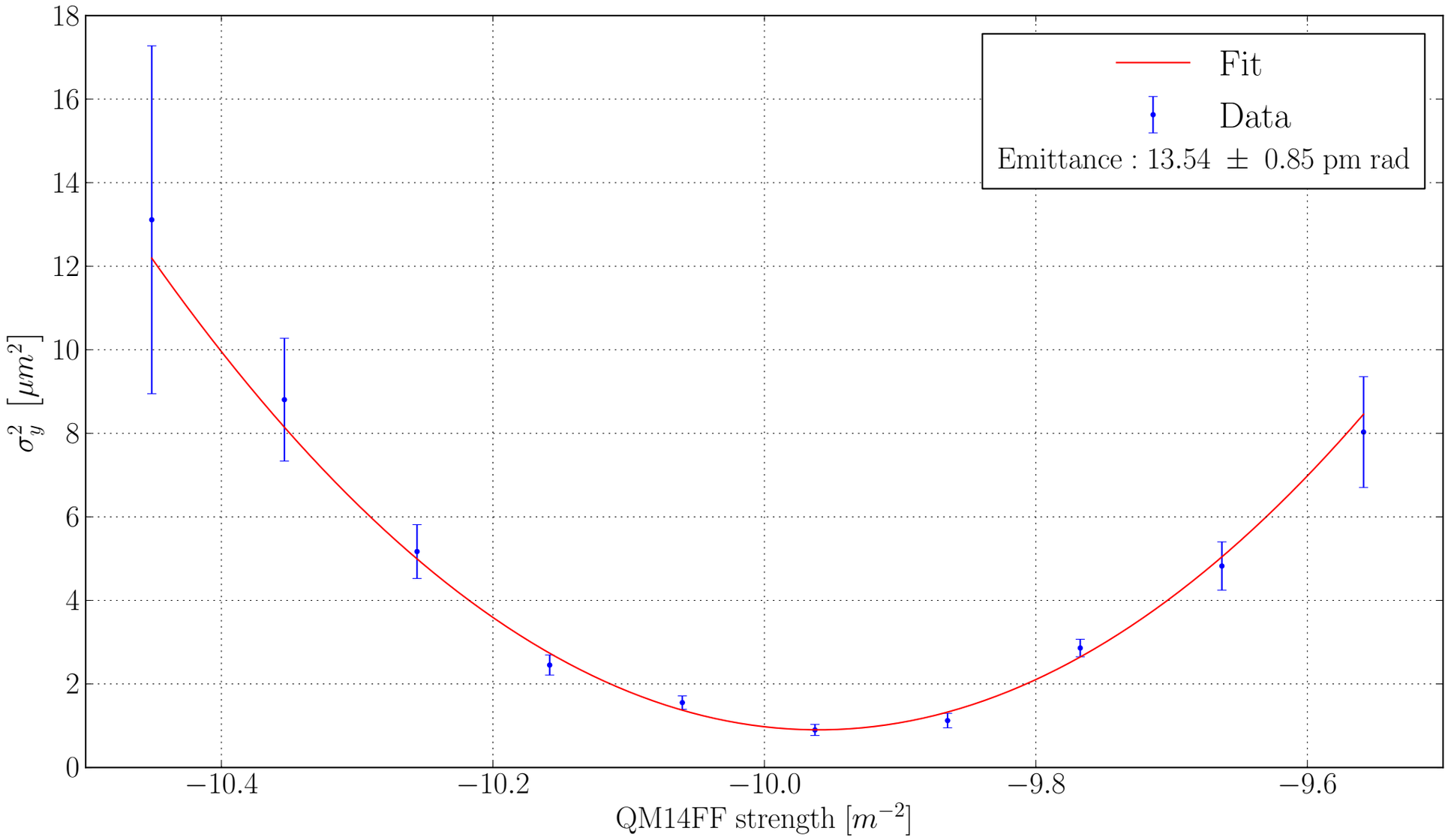
EMITTANCE



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SUMMARY

- No new data taken since spring 2013
- Focus on data analysis
    - Analysis code converted to python for future project
    - Choice of window size
    - emittance calculation
- Plan to publish paper to Journal of Instrumentation

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