

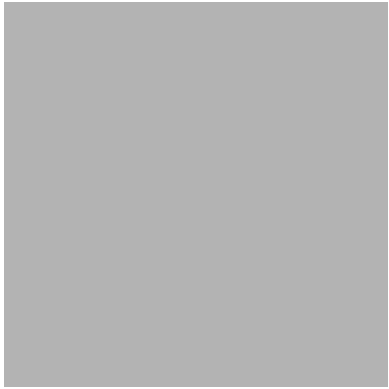


Initial Model Bias CTF Correction

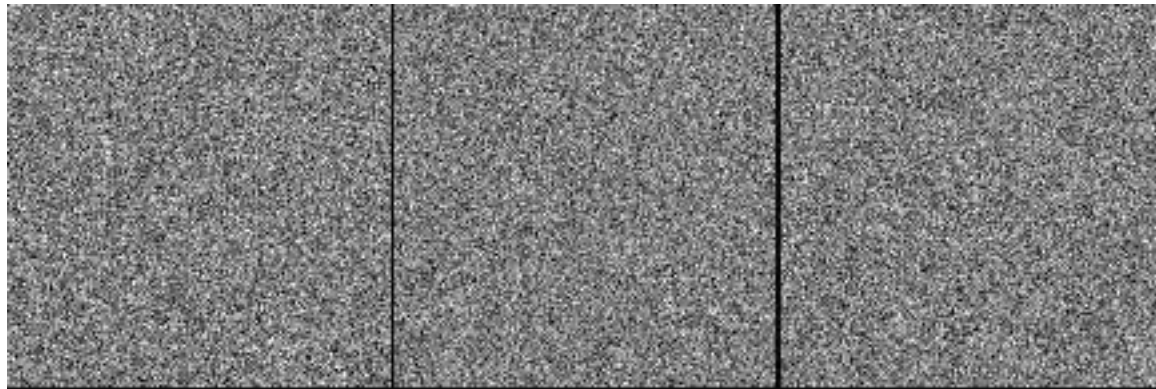
Steven Ludtke

Model Bias

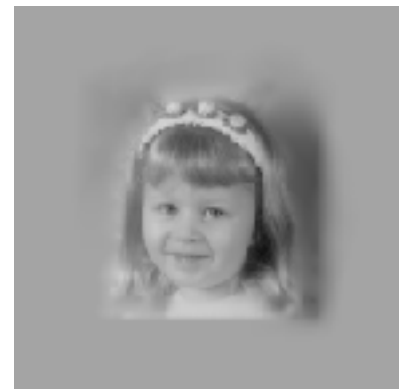
Base



Noisy

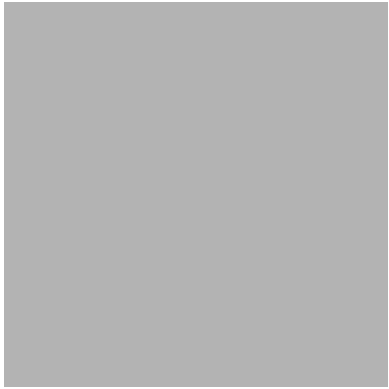


Align to

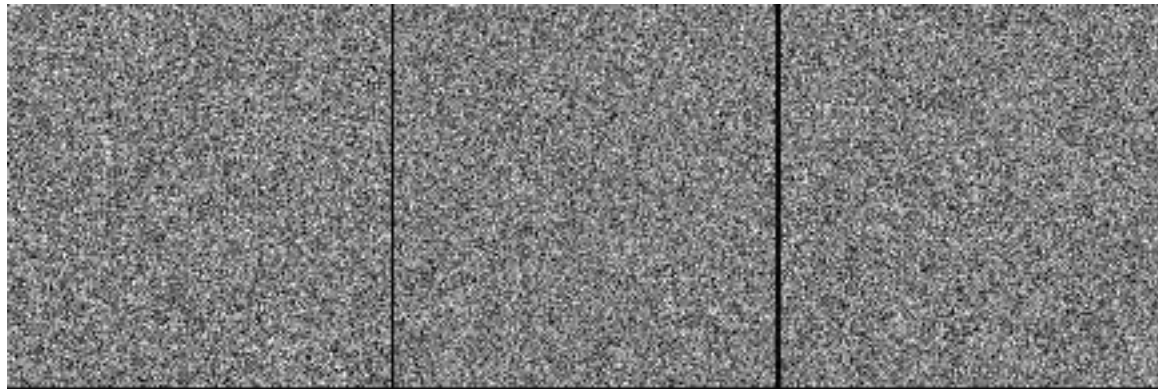


Model Bias

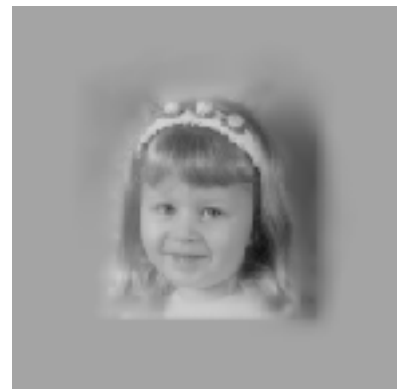
Base



Noisy



Align to



25

100

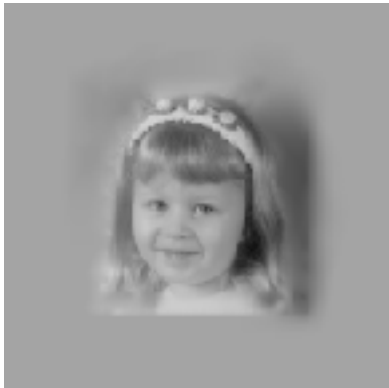
250

1000

2000

Model Bias

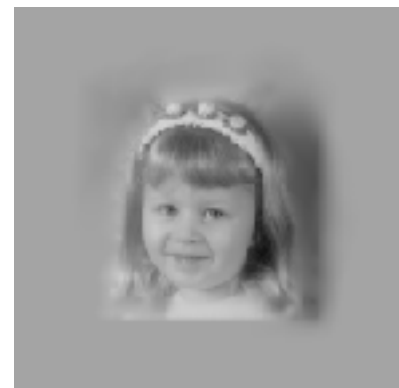
Base



Noisy (~10% contrast)



Align to



25

100

250

1000

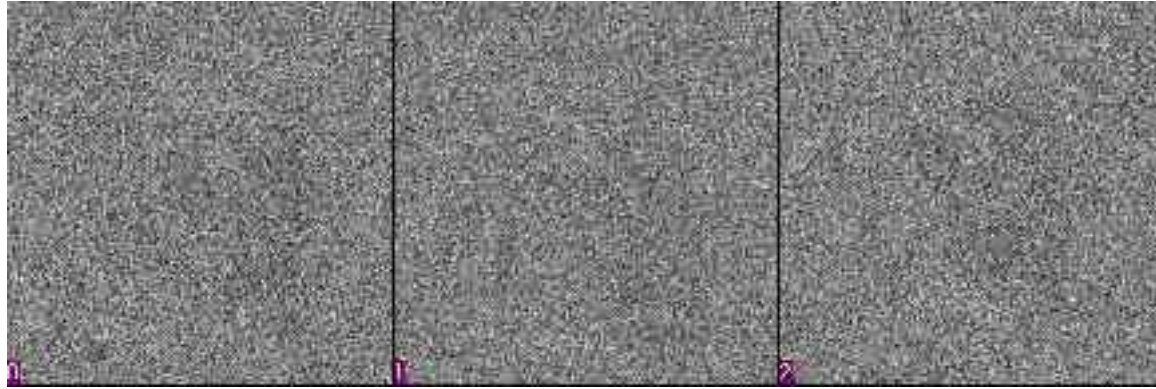
2000

Model Bias

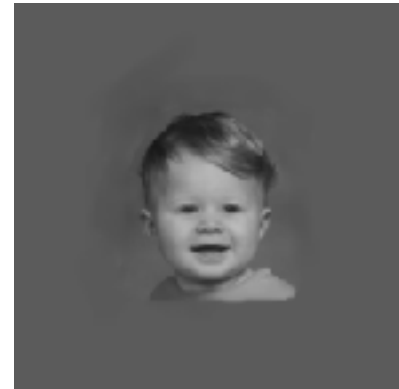
Base



Noisy (~10% contrast)



Align to

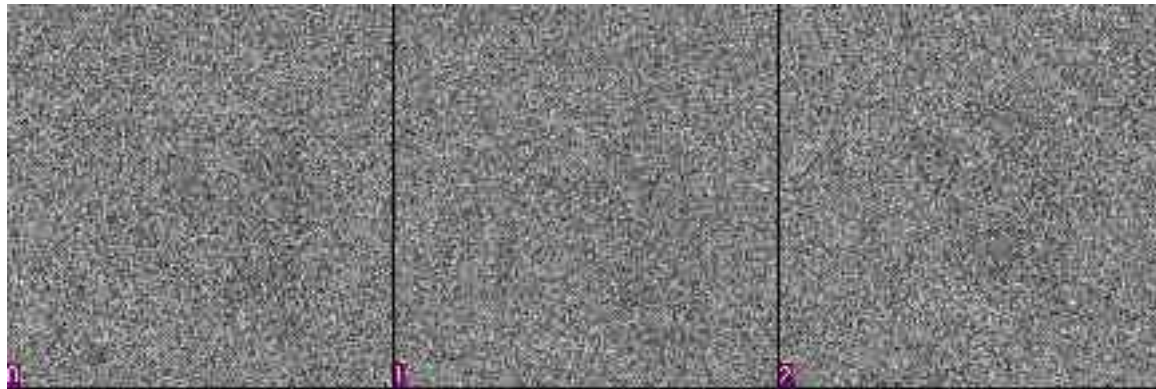


Model Bias

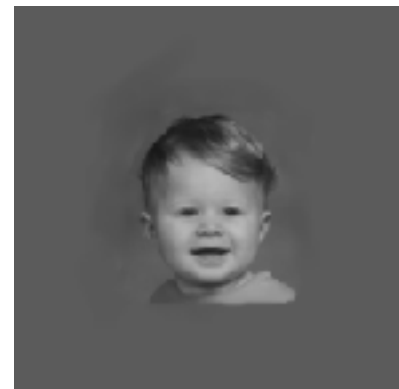
Base



Noisy (~10% contrast)



Align to



25

100

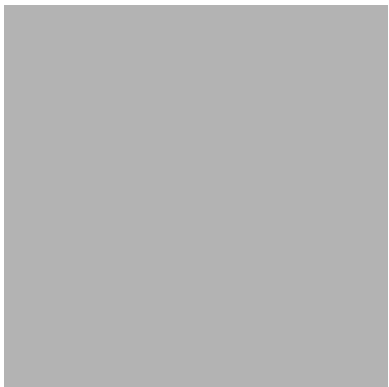
250

1000

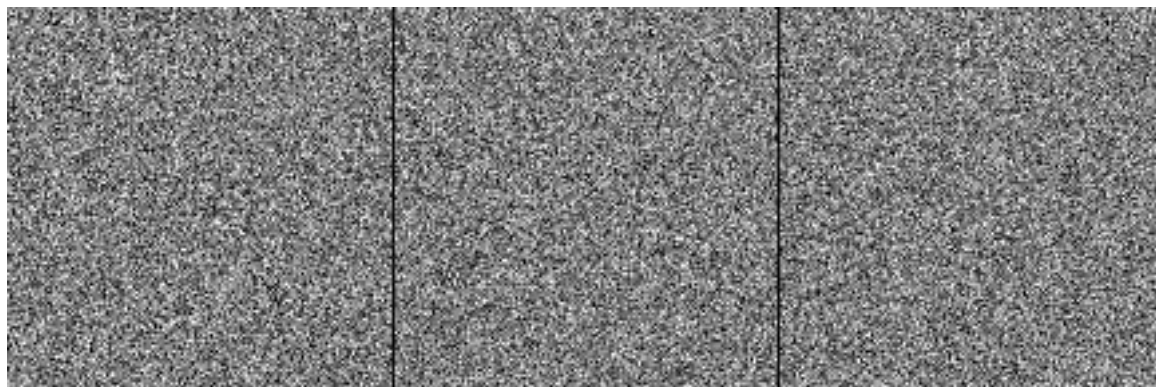
2000

Model Bias

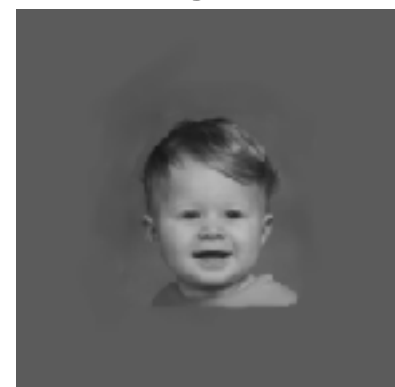
Base



Noisy



Align to



25

100

250

1000

2000

Model Bias

Base

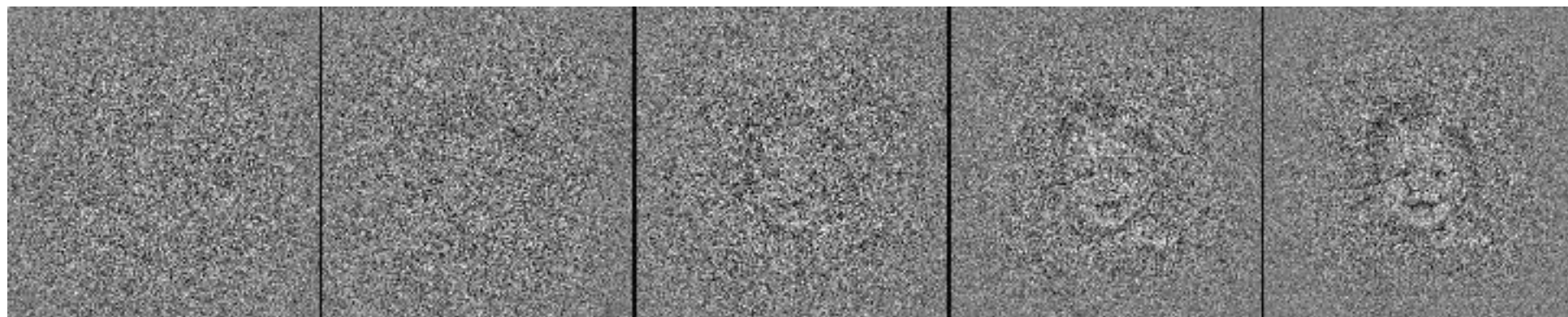


Noisy



Align to

Iter x4



25

100

250

1000

2000

Model Bias

Base

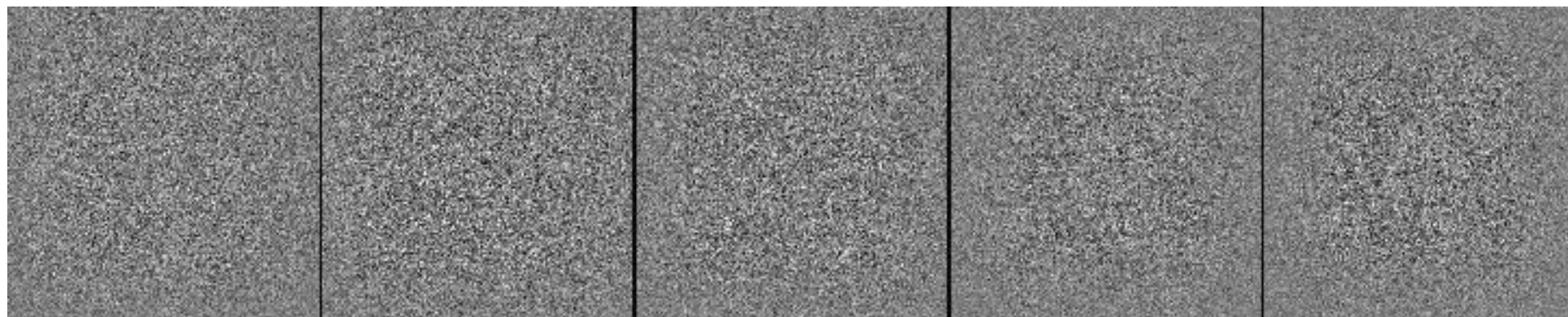


Noisy



Align to

Iter x8



25

100

250

1000

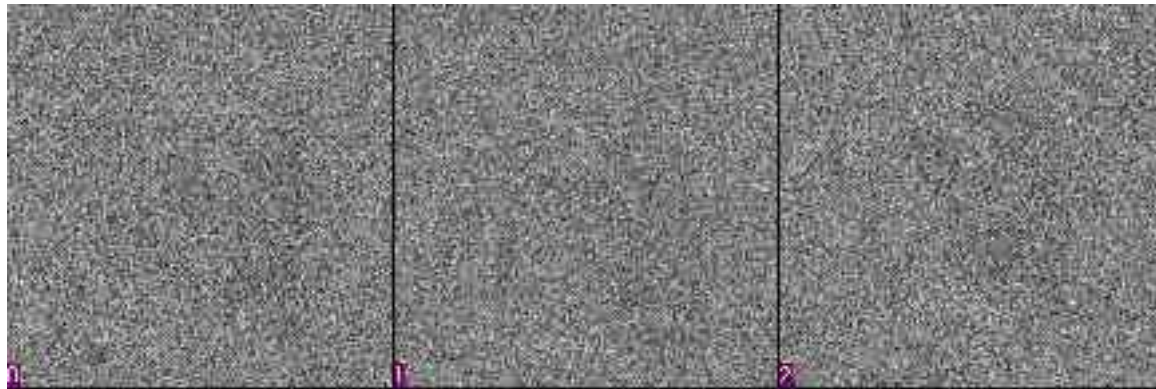
2000

Model Bias

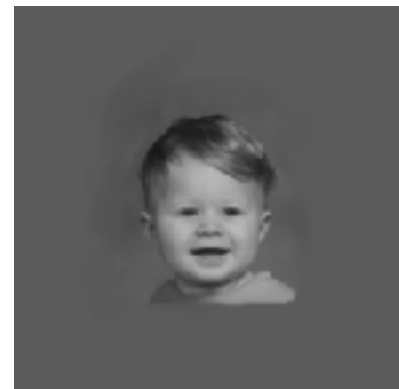
Base



Noisy (~10% contrast)



Align to



25

100

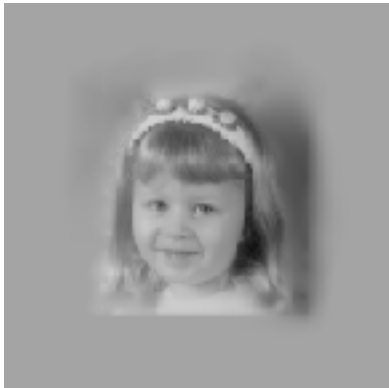
250

1000

2000

Model Bias

Base



Noisy



Align to



Iter x4



25

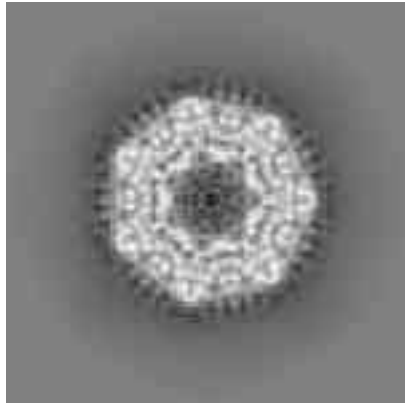
100

250

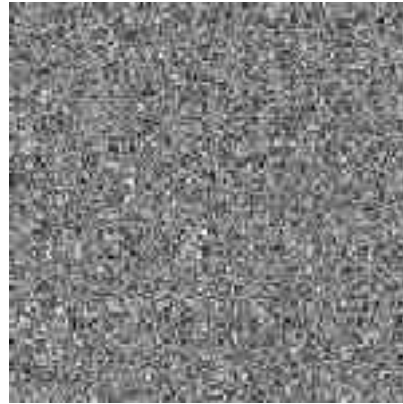
1000

2000

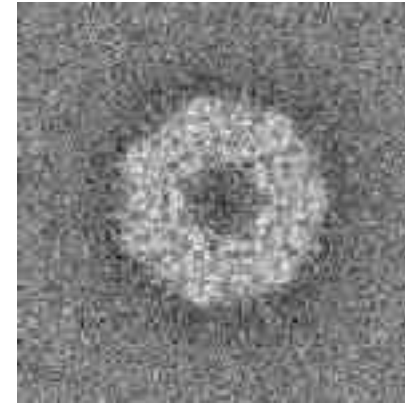
Wiener Filter



+



=



$I(r, \theta)$

$N(r, \theta)$

$M(r, \theta)$

$\tilde{I}(s, \theta)$

$\tilde{N}(s, \theta)$

$\tilde{M}(s, \theta)$

Wiener Filter

$$\tilde{R}(s) = F(s) \cdot \tilde{M}(s)$$

Wiener Filter

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$$\int_{-\infty}^{\infty} |R(x) - I(x)|^2 dx$$

Wiener Filter

$$\tilde{R}(s) = F(s) \cdot \tilde{M}(s)$$

$$\int_{-\infty}^{\infty} |R(x) - I(x)|^2 dx = \int_{-\infty}^{\infty} |\tilde{R}(s) - \tilde{I}(s)|^2 ds$$

Minimize wrt $F(s)$

Wiener Filter

$$\tilde{R}(s) = F(s) \cdot \tilde{M}(s)$$

$$\int_{-\infty}^{\infty} |R(x) - I(x)|^2 dx = \int_{-\infty}^{\infty} |\tilde{R}(s) - \tilde{I}(s)|^2 ds$$

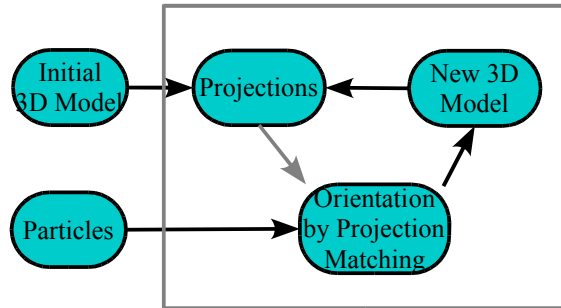
Minimize wrt $F(s)$

$$\frac{\partial}{\partial F(s)} \int_{-\infty}^{\infty} |F(s)(\tilde{I}(s) + \tilde{N}(s)) - \tilde{I}(s)|^2 ds = 0$$

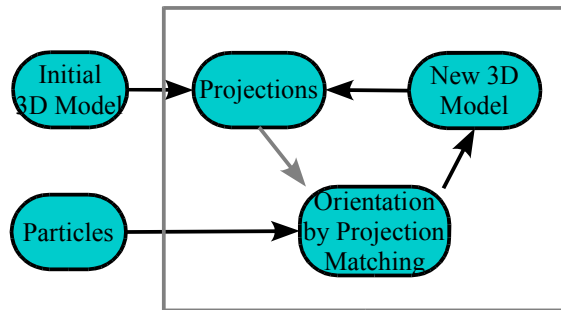
$$F(s) = \frac{|\tilde{I}(s)|^2}{|\tilde{I}(s)|^2 + |\tilde{N}(s)|^2} = \frac{1}{1 + \frac{|\tilde{N}(s)|^2}{|\tilde{I}(s)|^2}}$$

CTF Correction - Spider

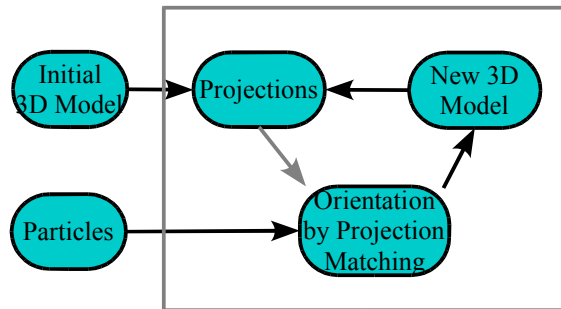
Defocus 1



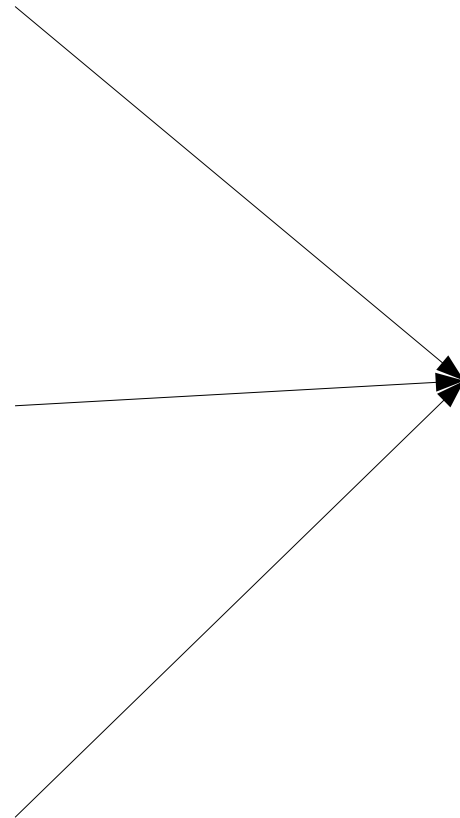
Defocus 2



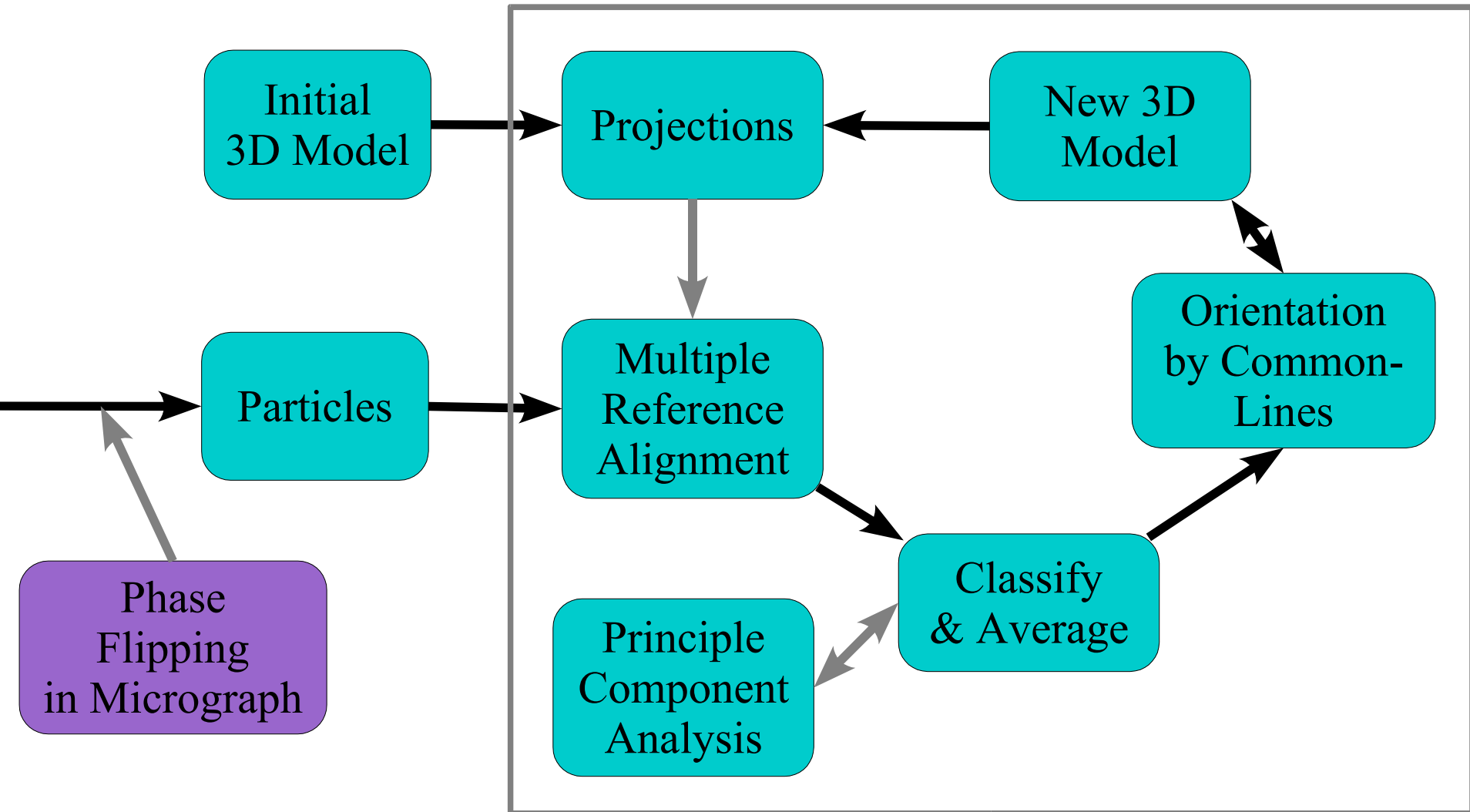
Defocus 3



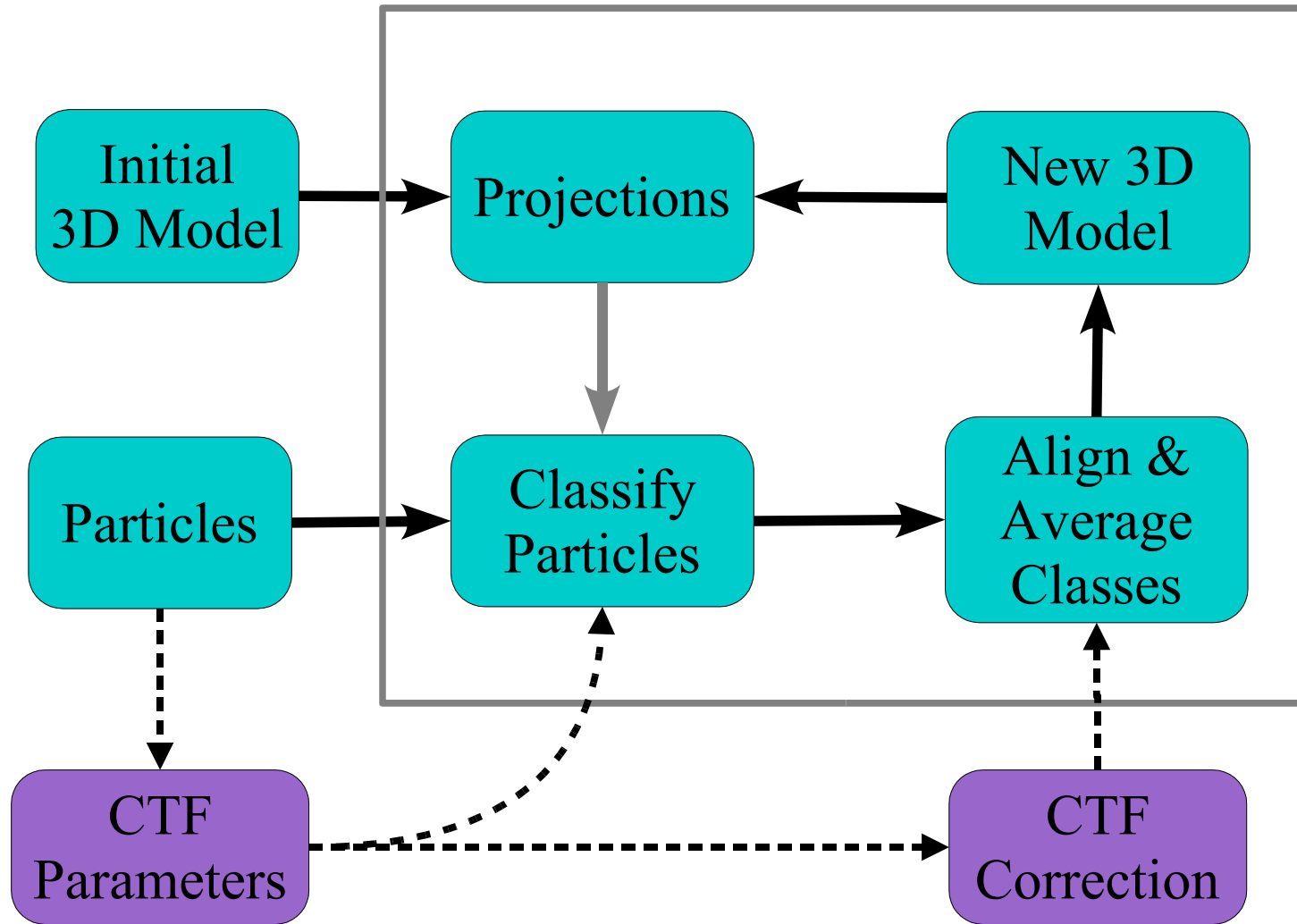
CTF Correct and Merge in 3D



CTF Correction - Imagic



CTF Correction - EMAN



Possible Corrections

- Phase flipping
 - Astigmatism
- Amplitude contrast correction
- Envelope function correction
 - Drift
 - Multi-parameter envelope
- Inter-micrograph weighting

Contrast Transfer Function

$$\overline{M}(s, \theta) = \overline{F}(s, \theta) C(s) E(s) + \overline{N}(s, \theta)$$

$$C(s) = \sqrt{1 - Q^2} \sin y + Q \cos y$$

$$y = -\pi \left(\frac{1}{2} C_s \lambda^3 s^1 - \Delta Z \lambda s^2 \right)$$

$$E(s) = e^{-B s^2}$$

$$N^2 = n_1 e^{n_2 s + n_3 s^2 + n_4 \sqrt{s}}$$

$$M(s)^2 = F(s)^2 C(s)^2 E(s)^2 + N(s)^2$$

8 Parameters

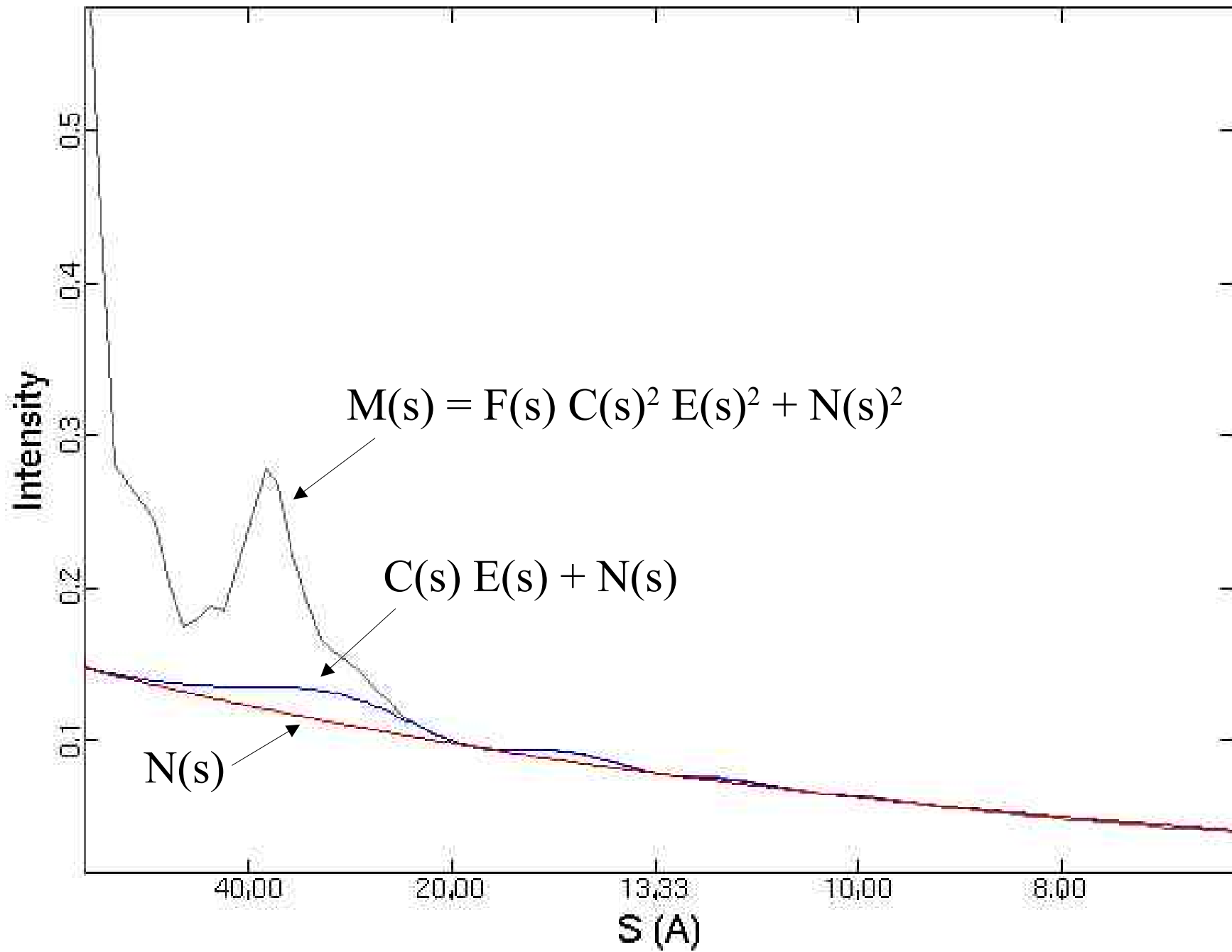
ΔZ - Defocus

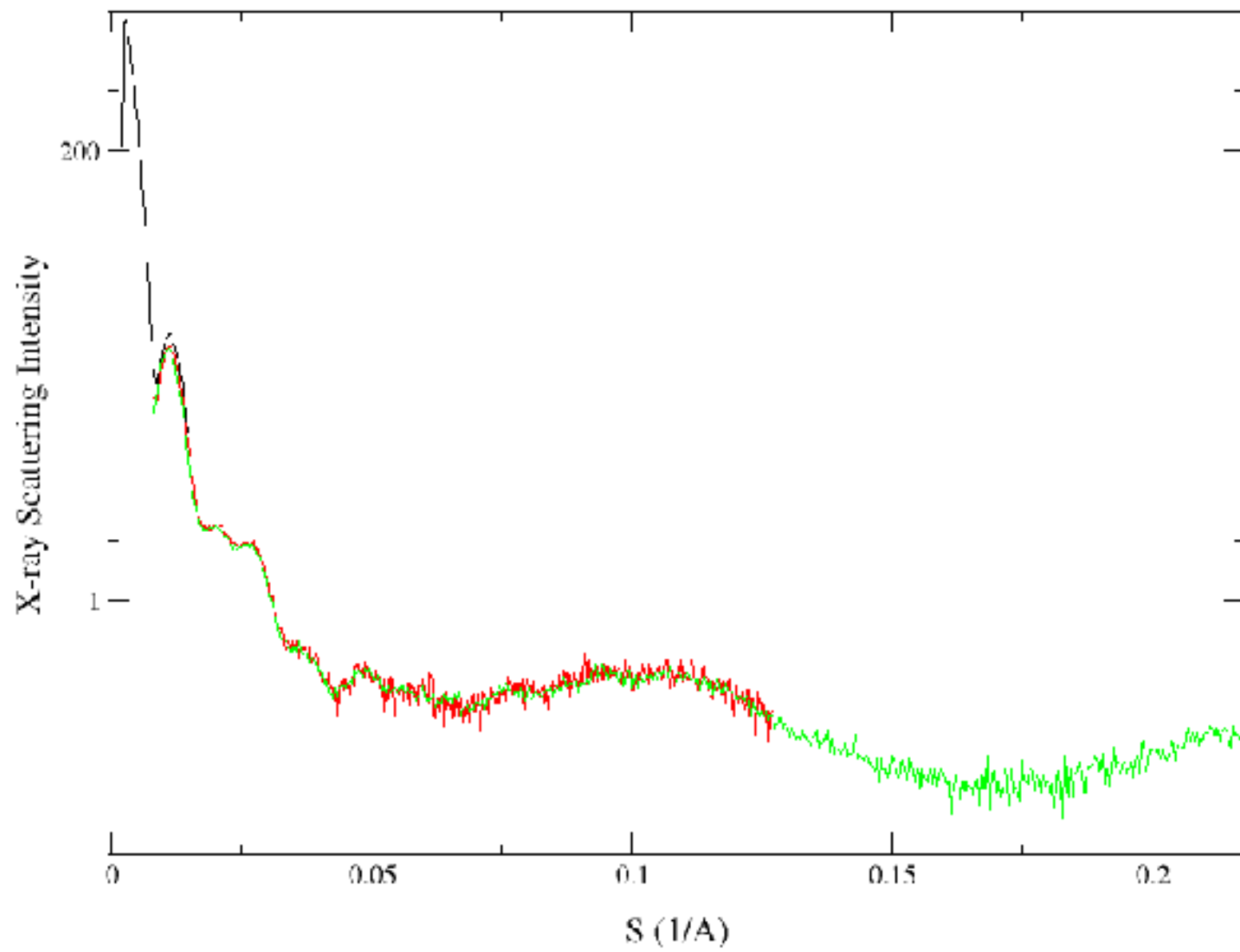
Q - Amplitude Contrast

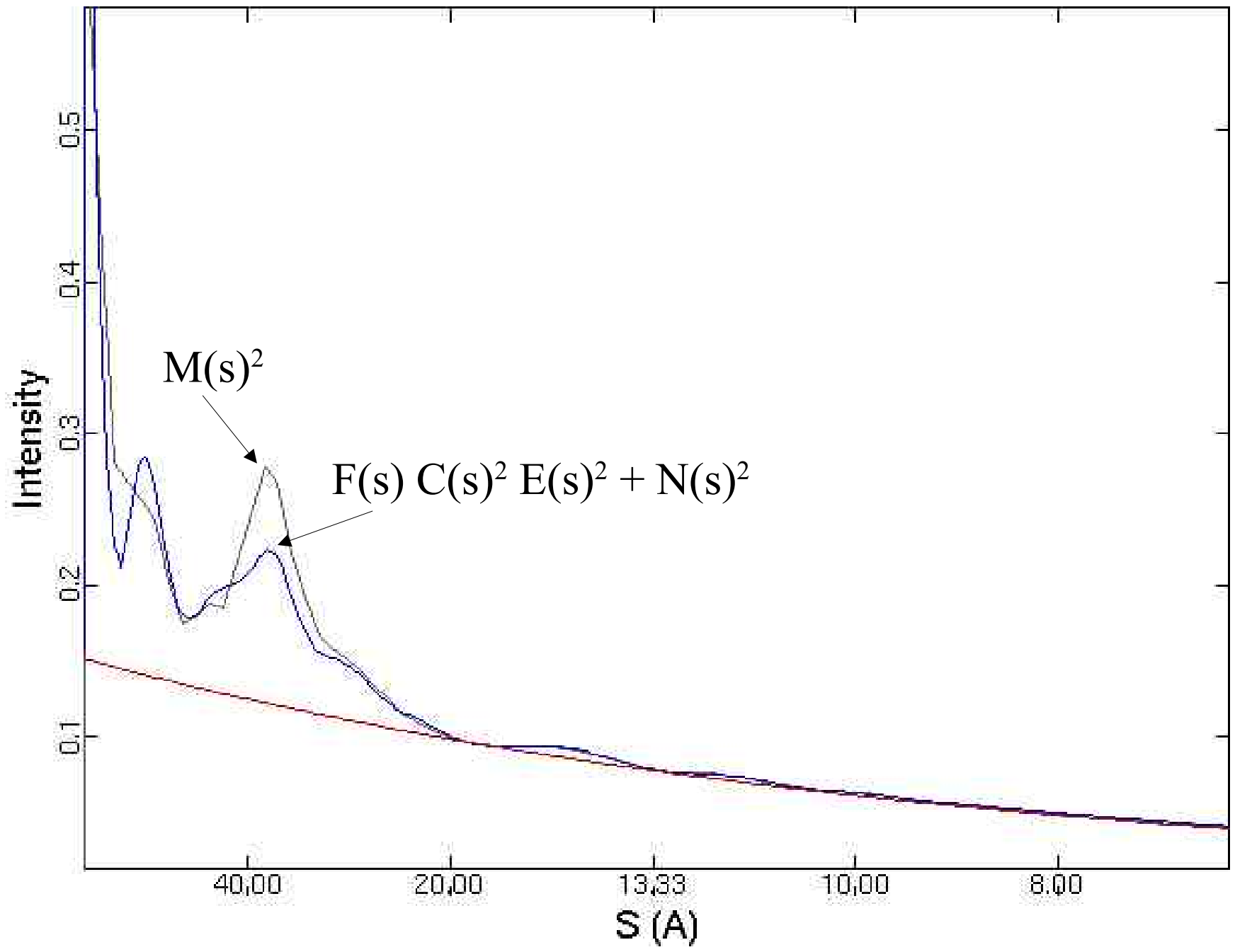
B - Gaussian Envelope Width

k - Signal Amplitude

n_{1-4} - Noise Parameters







CTF Correction

$$\bar{T}(s, \theta) = \sum_i k_i \bar{M}_i(s, \theta)$$

$$k_i = ?$$

- Maximize SNR of $T(s, q)$
- Minimize variance between $T(s, q)$ and $F(s, q)$

CTF Correction

Wiener
Filter

CTF
Correction

SNR
Weight

$$\bar{T}(s, \theta) = \frac{F^2(s) R(s)}{1 + F^2(s) R(s)} \sum_i \frac{1}{C_i(s) E_i(s)} \frac{R_i(s)}{R(s)} \bar{M}_i(s, \theta)$$

$$R_i(s) = \frac{C_i^2(s) E_i^2(s)}{N_i^2(s)}$$

$$R(s) = \sum_i \frac{C_i^2(s) E_i^2(s)}{N_i^2(s)}$$