



# Correcting Substrate Warp for X-Ray Reflectometry

By: Pavan Bhargava



# Outline

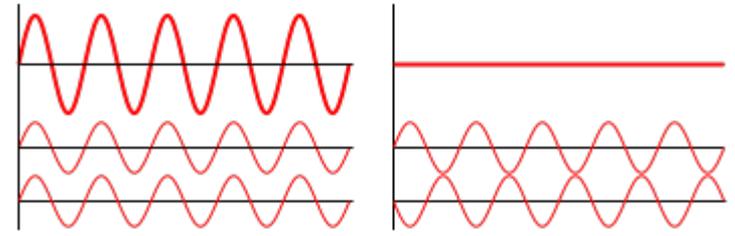
- What is reflectometry?
  - How reflectometry works
  - Correction factors
- What is warp?
  - Complications with warp
- Warp Correction Methods
  - Software Correction
  - Vacuum Flattening
  - Slit Control

# What is Reflectometry?

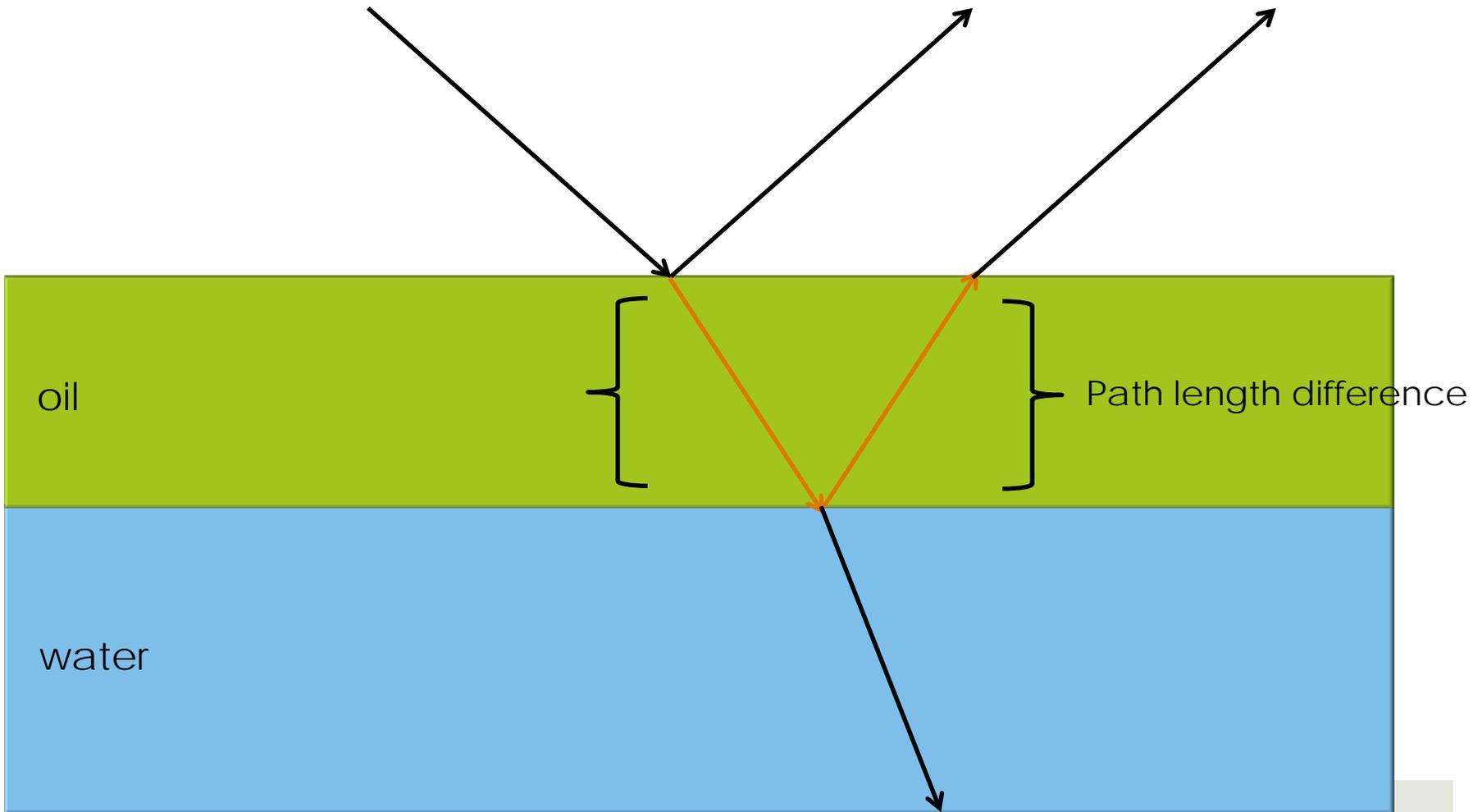


Reflected Intensity dependent on:

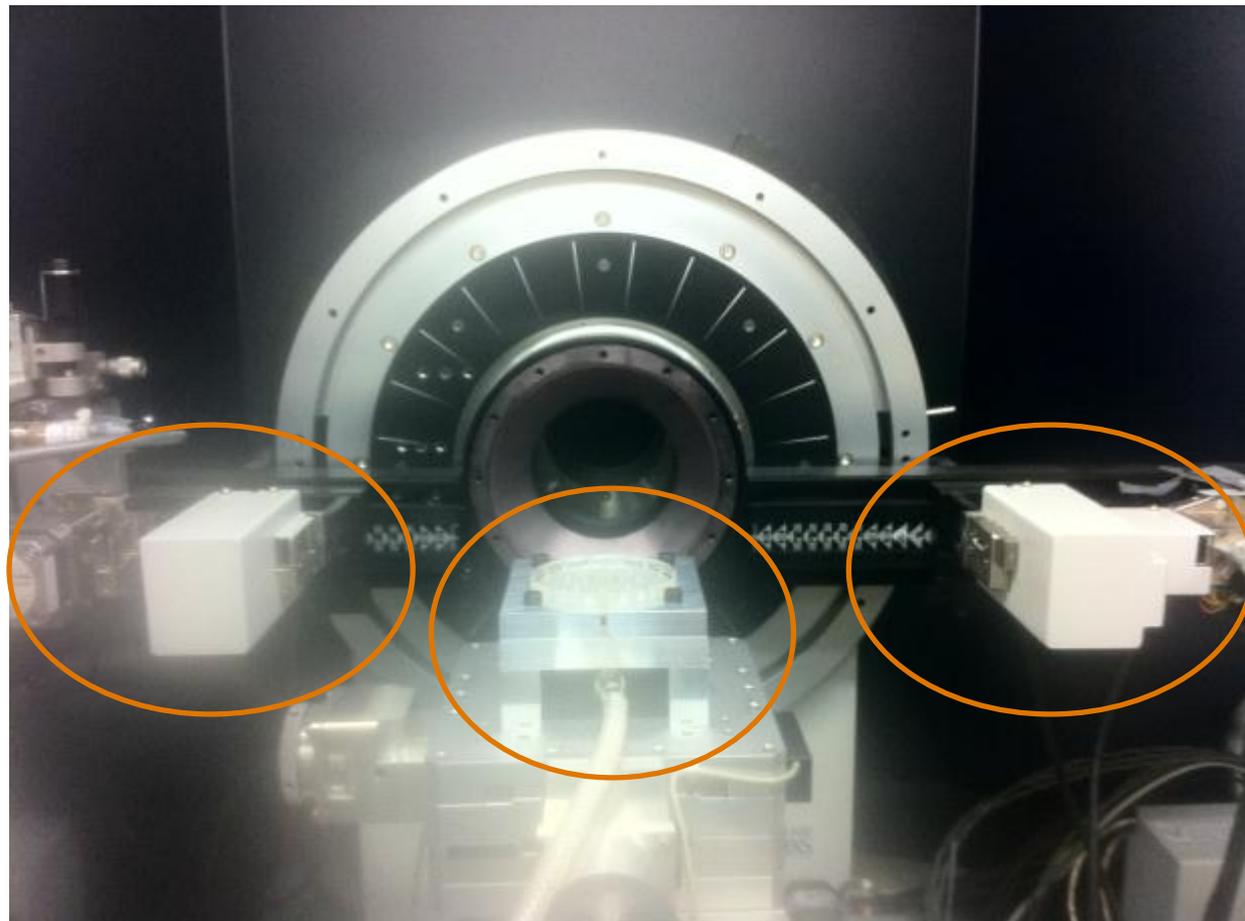
- Incident Angle
- Wavelength
- Layer Composition
- Layer Thickness



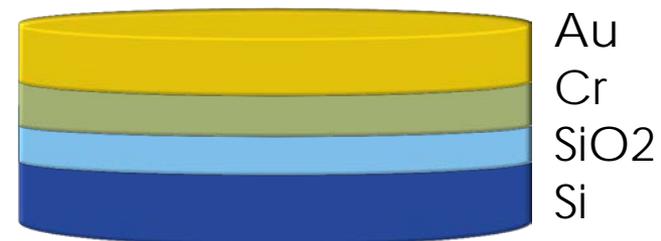
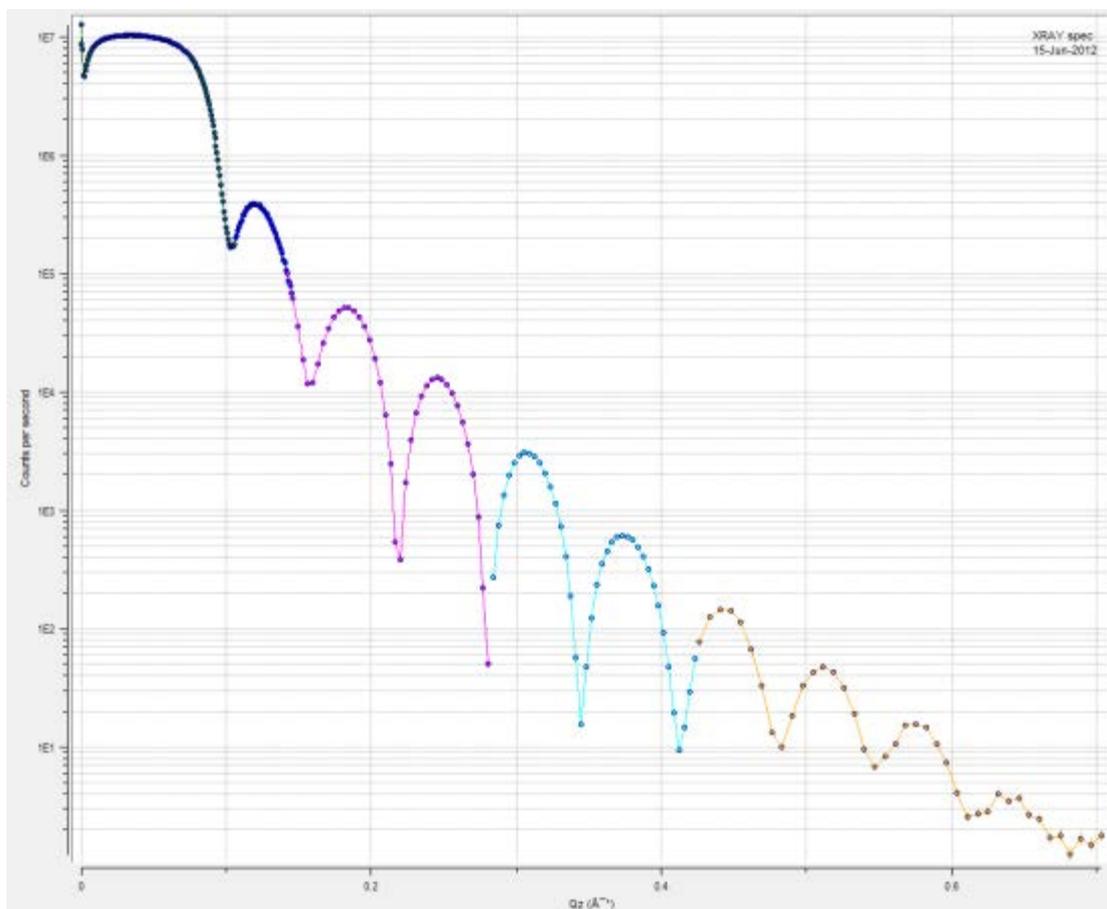
Constructive Interference    Destructive Interference



# X-Ray Reflectometer Setup



# Reflectivity Curve

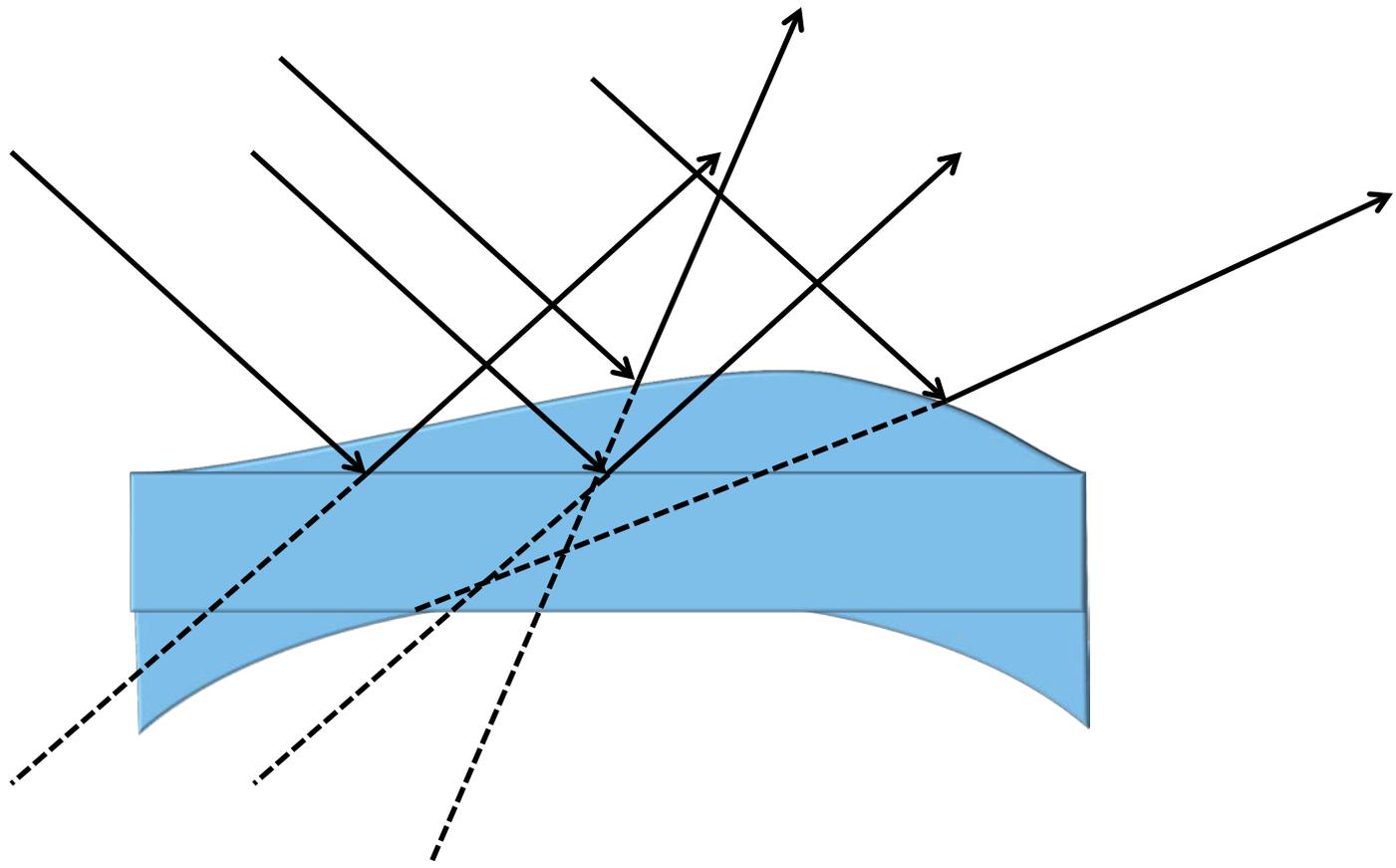




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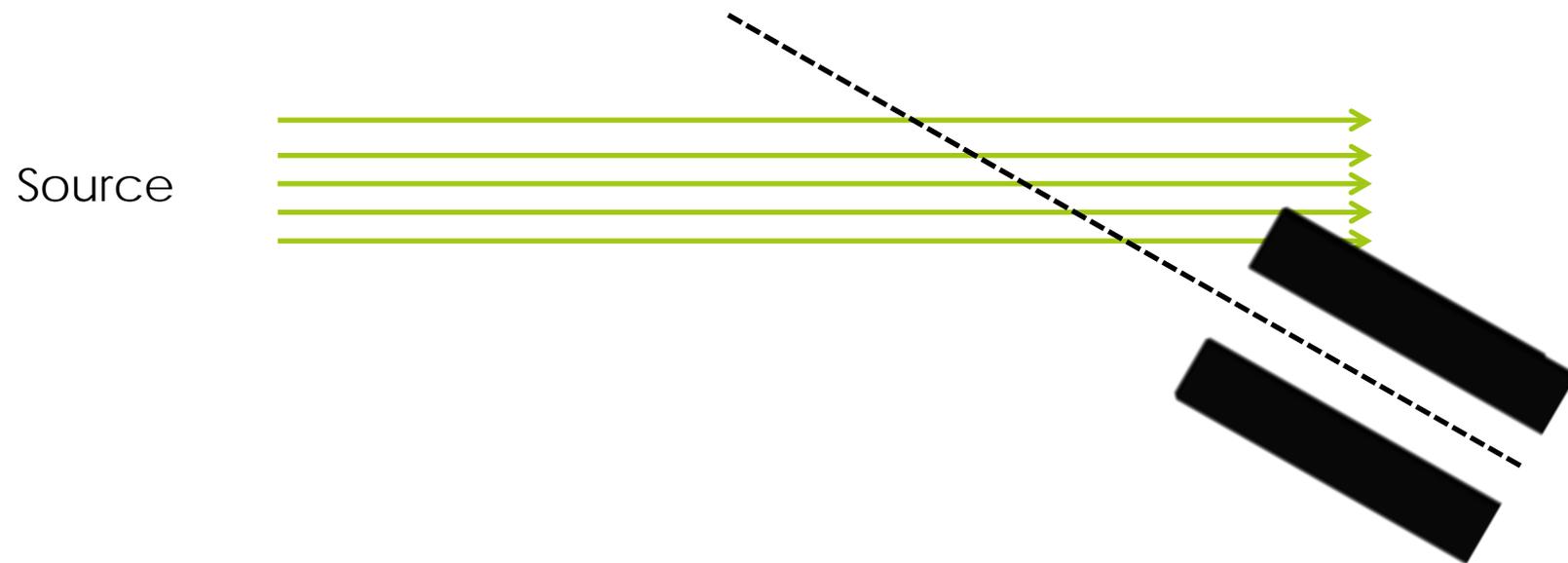
- What is reflectometry?
  - How reflectometry works
- Substrate warp
  - **Complications with warp**
- Warp Correction Methods
  - Software Correction
  - Vacuum Flattening
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# Substrate Warp

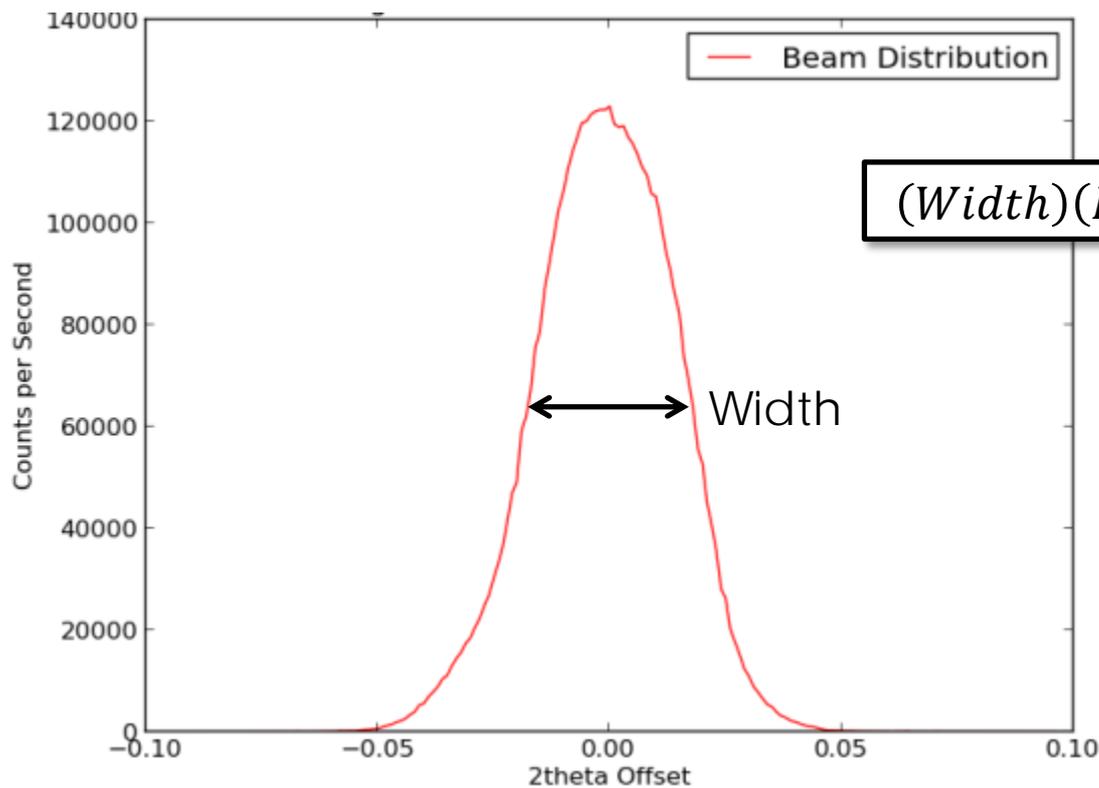




# Detector Scan

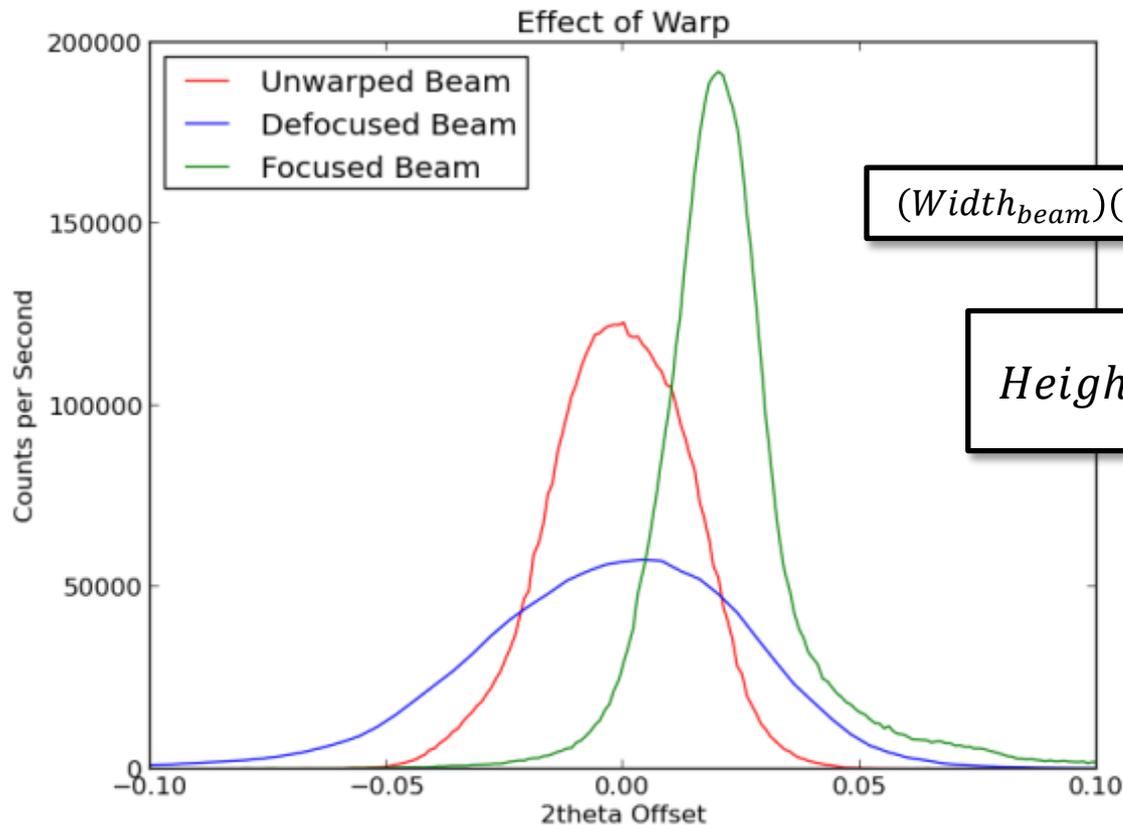


# Divergence of Incident Beam



$(Width)(Height) \propto \text{Integrated Intensity}$

# Warp Effects – Reflected Angle

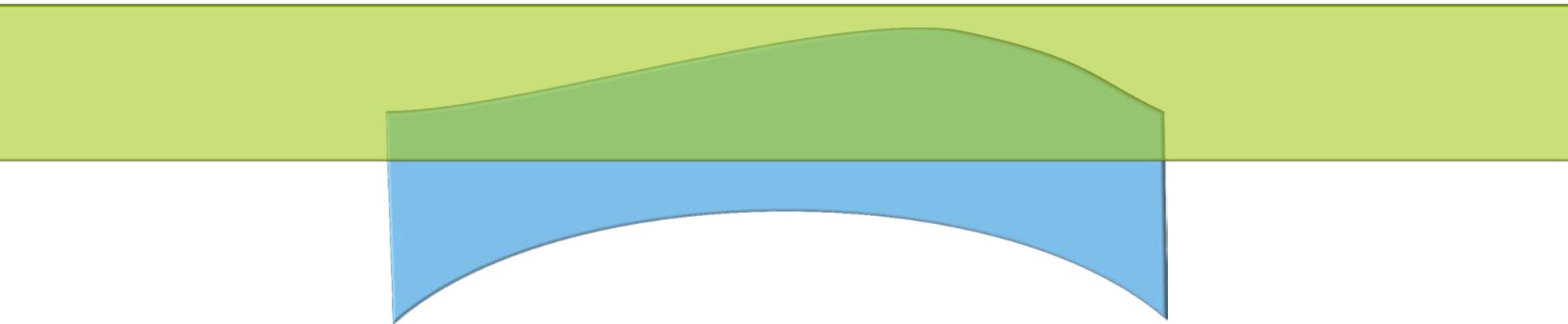


$$(Width_{beam})(Height_{beam}) = (Width_{warp})(Height_{warp})$$

$$Height_{beam} = \frac{Width_{warp}}{Width_{beam}} * Height_{warp}$$

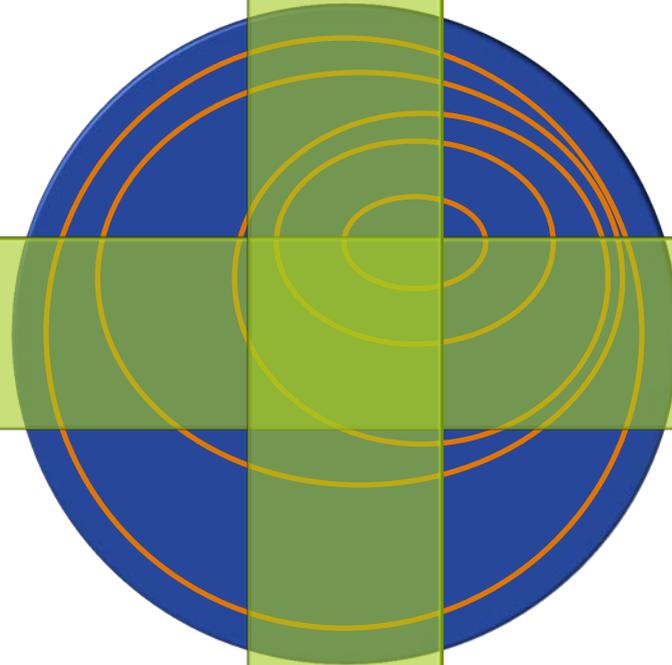


# Warp Effects - Footprint

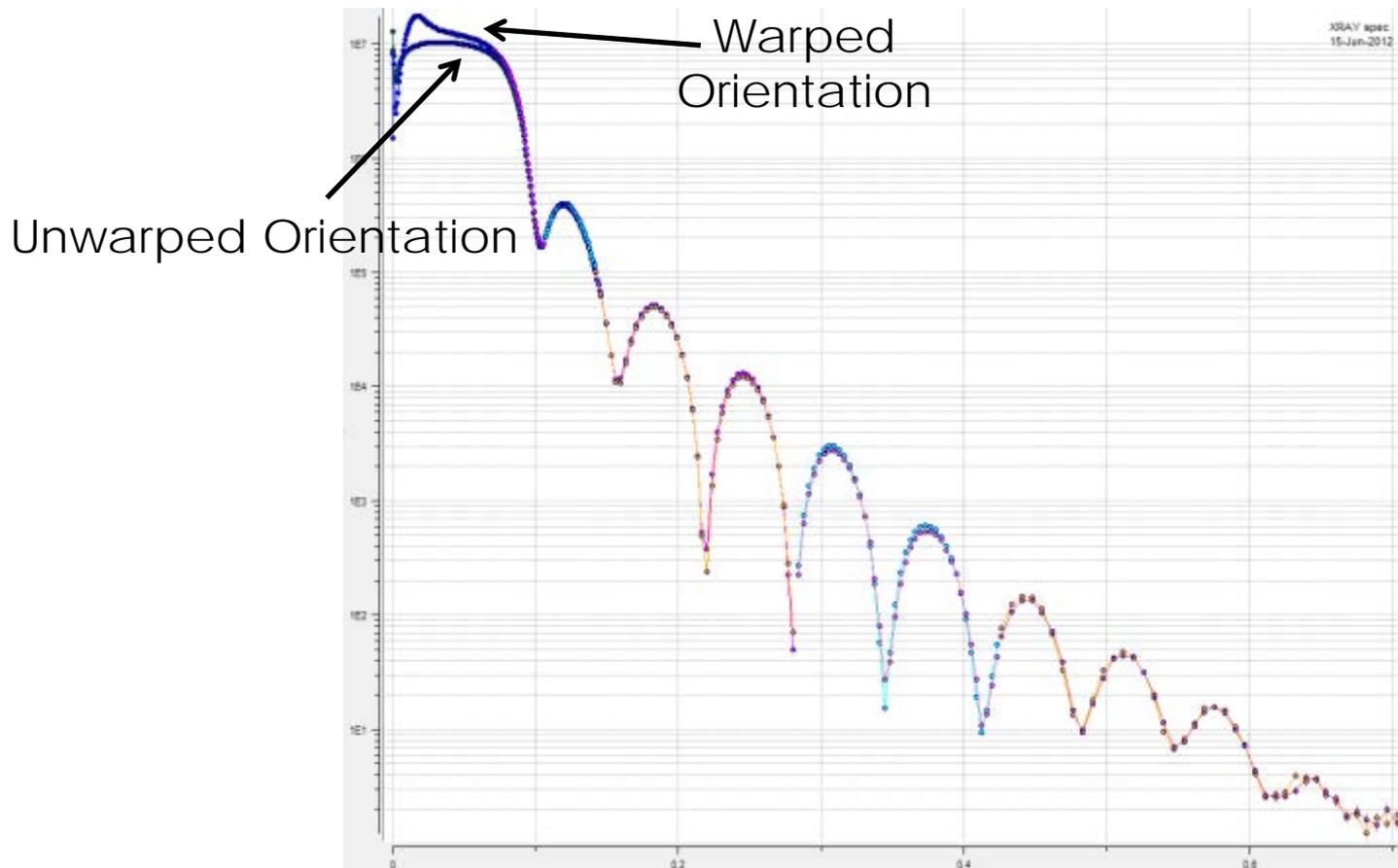




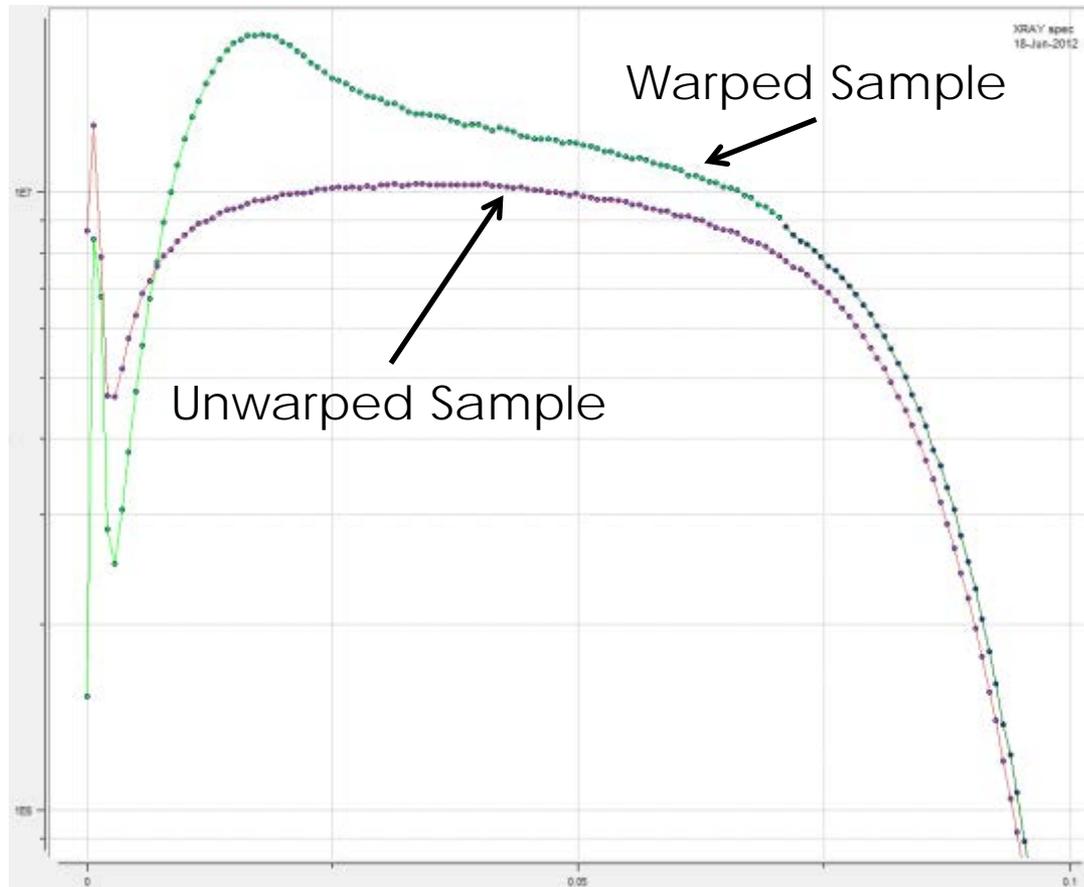
# The Experiment



# Warp Effects – Reflectivity



# Warp Effects – Reflectivity

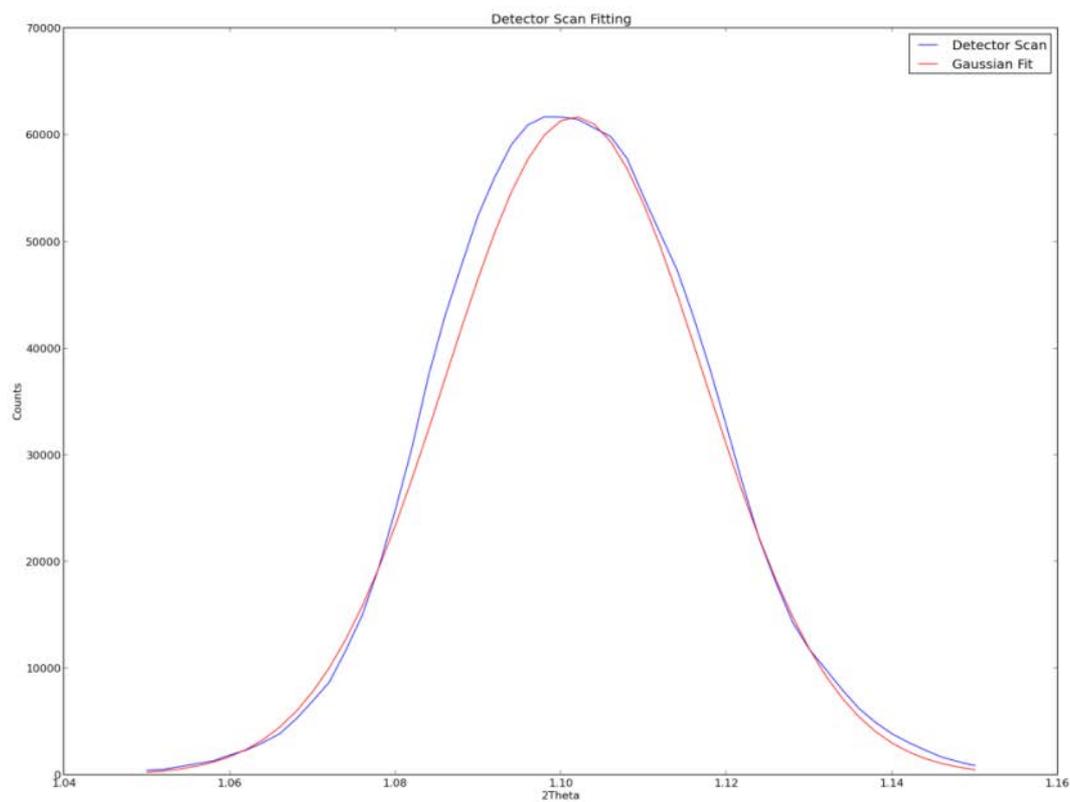




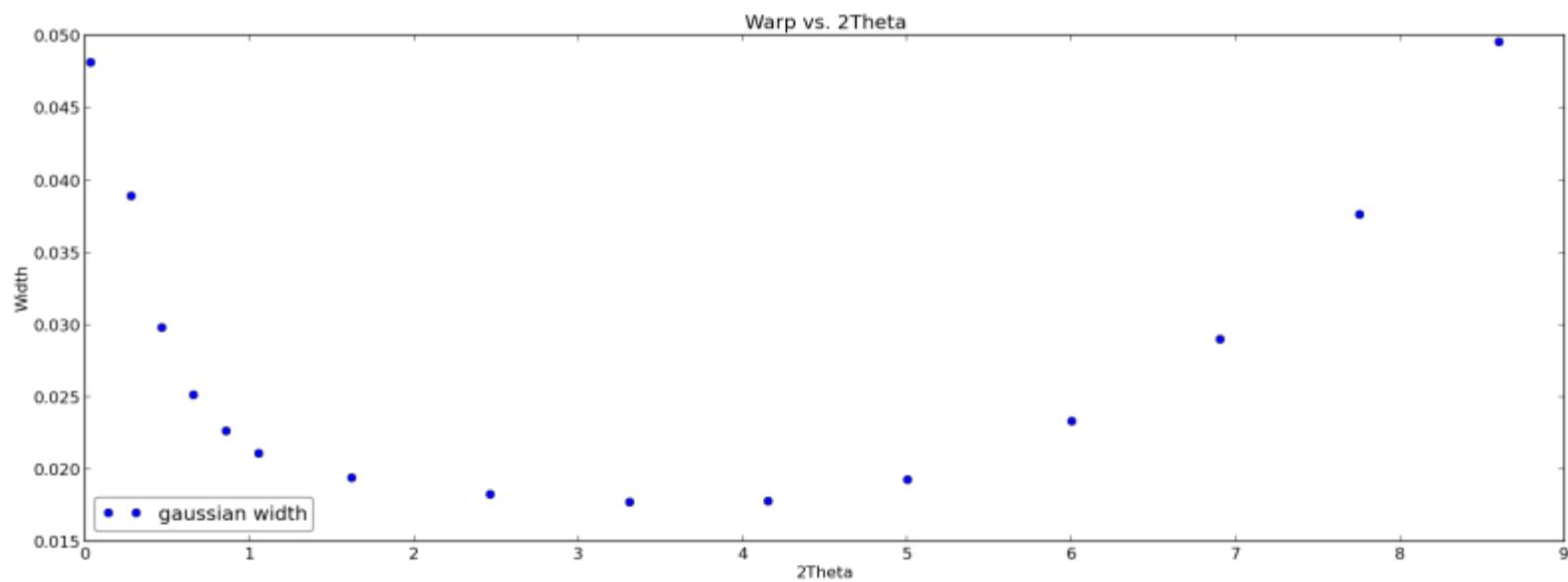
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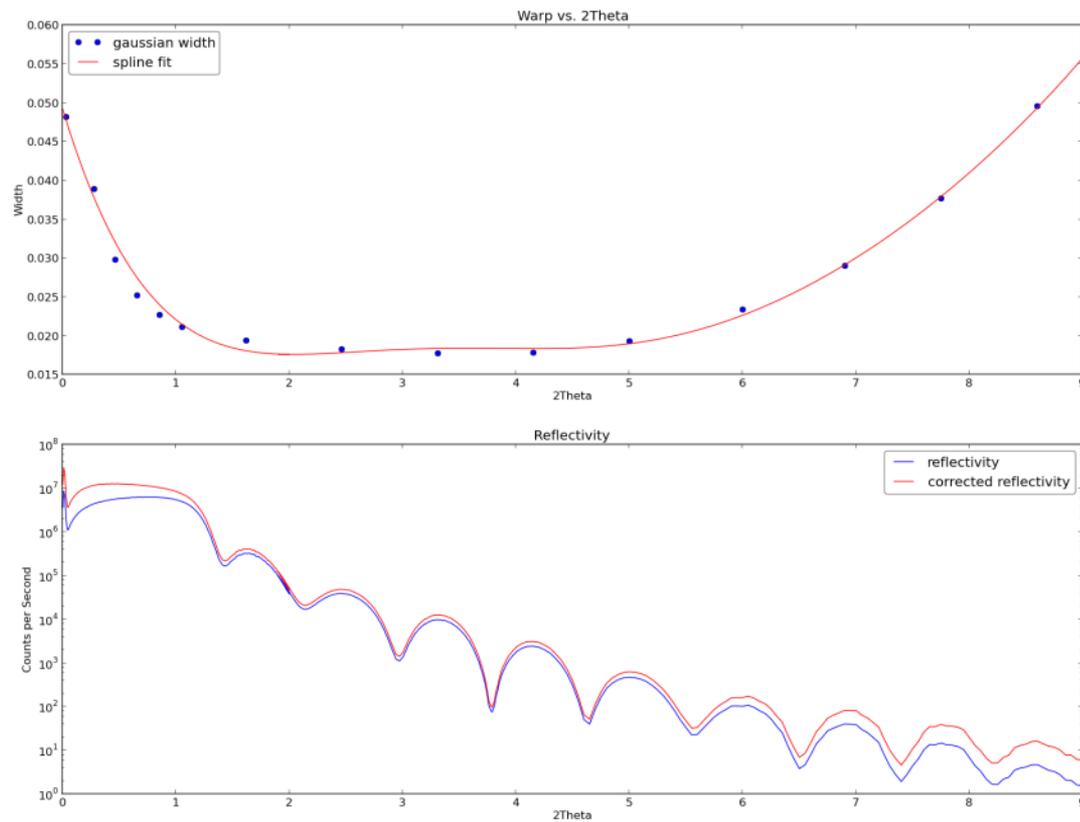
# Software Correction



# Software Correction

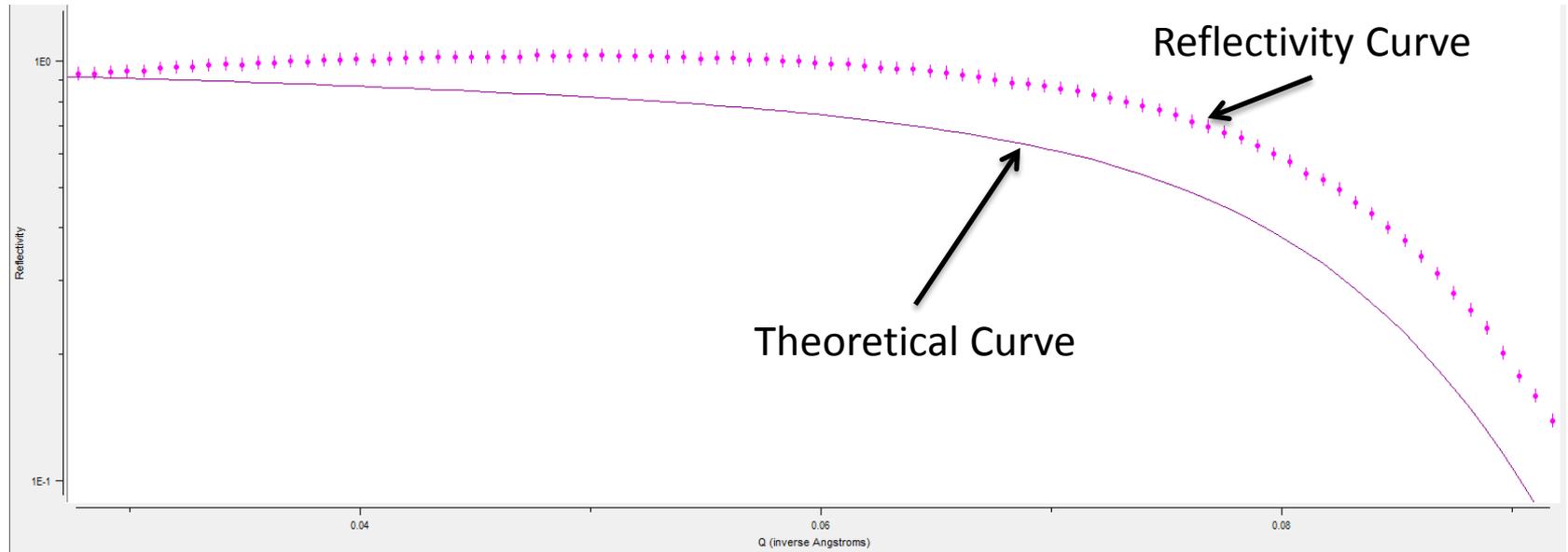


# Software Correction

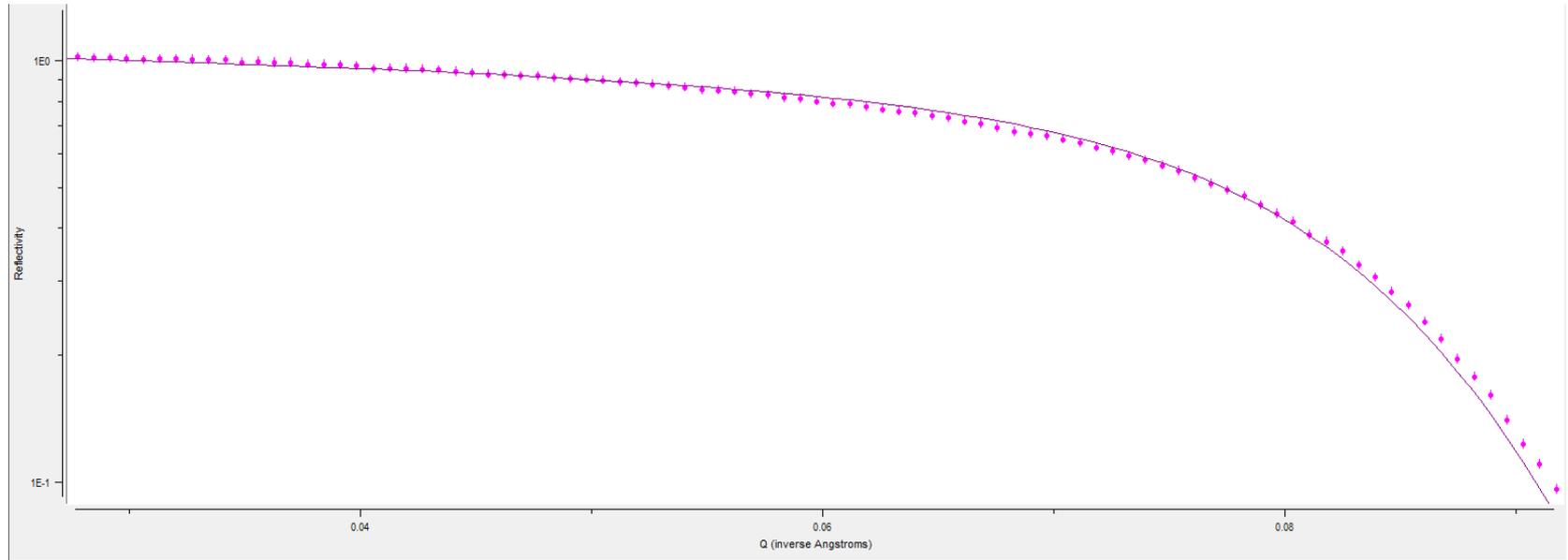




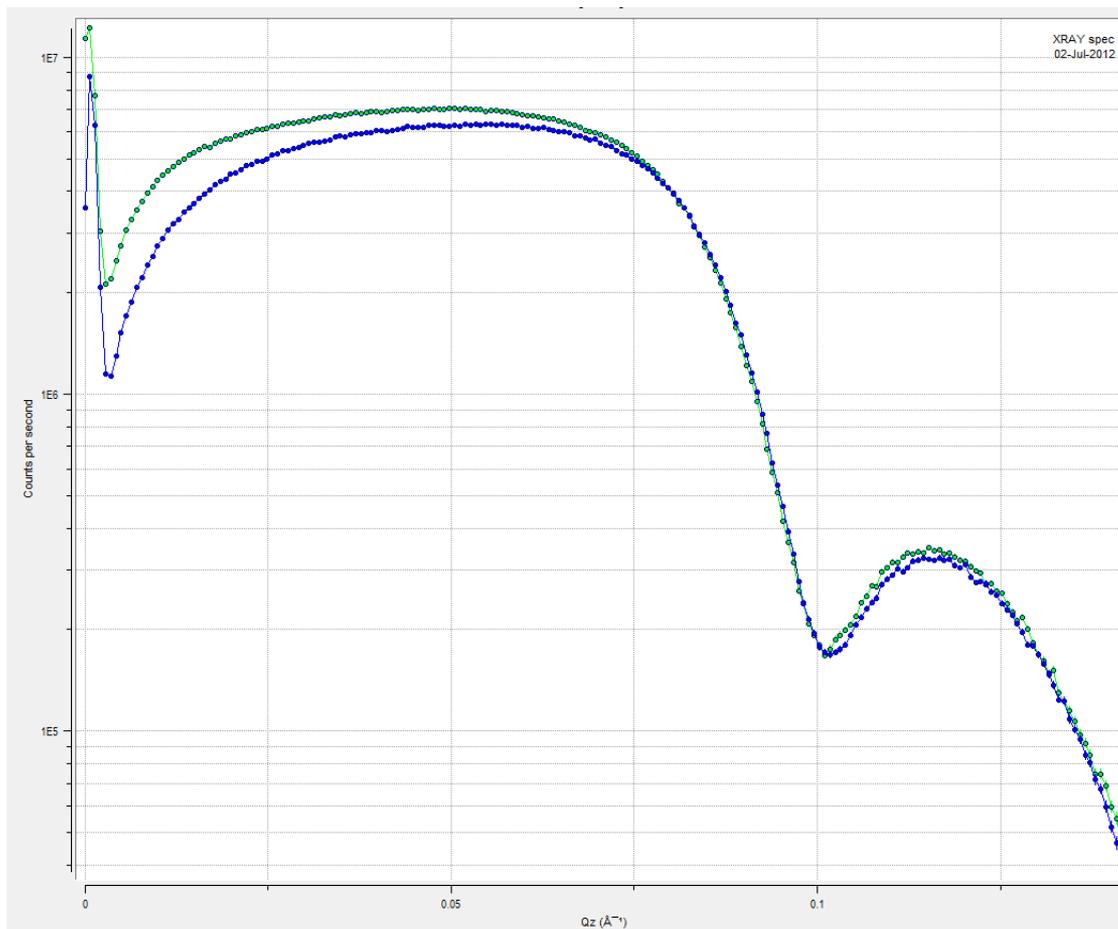
# Uncorrected Sample



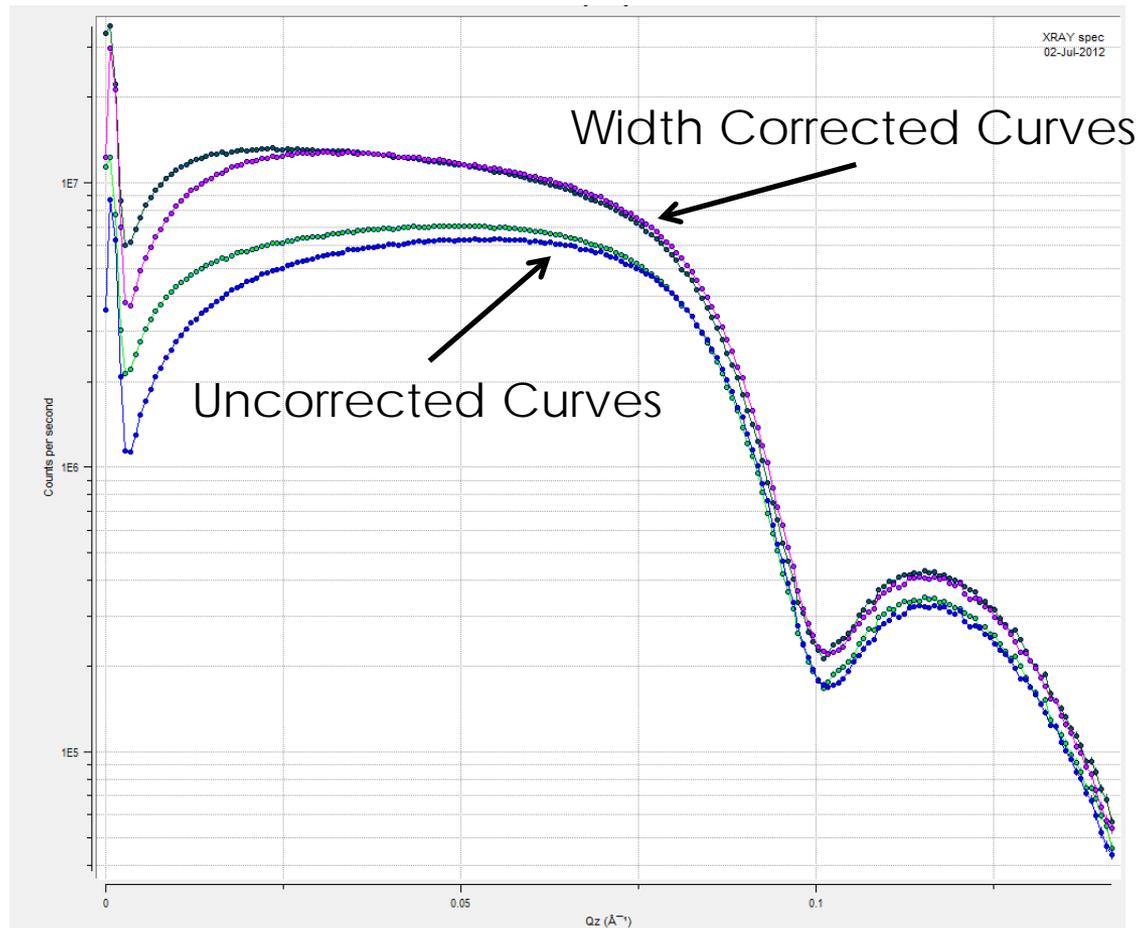
# Width Corrected Sample



# Uncorrected Reflectivity



# Corrections Converge

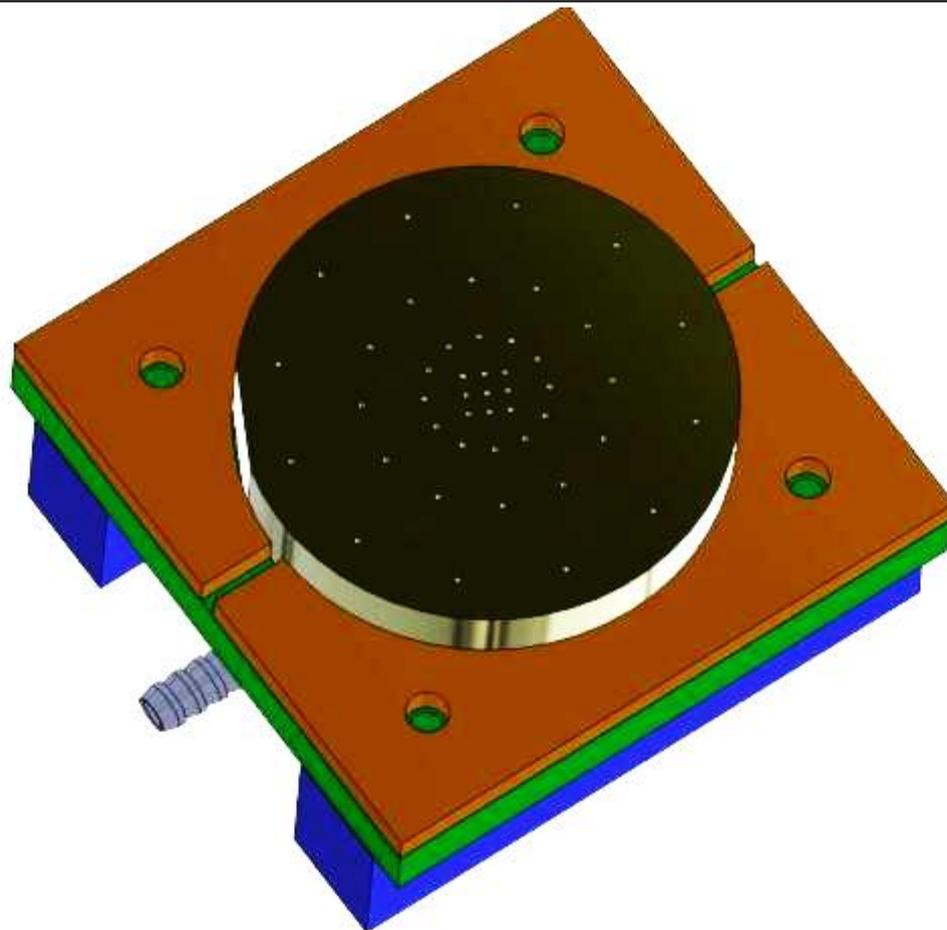




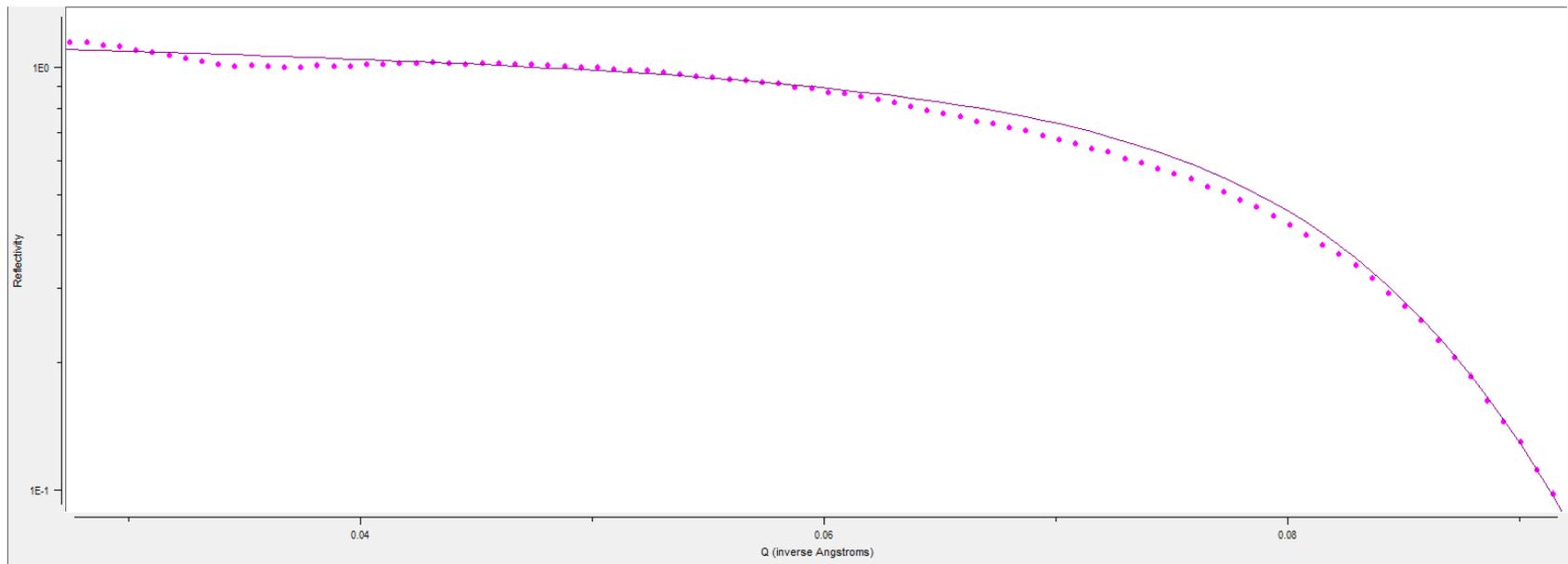
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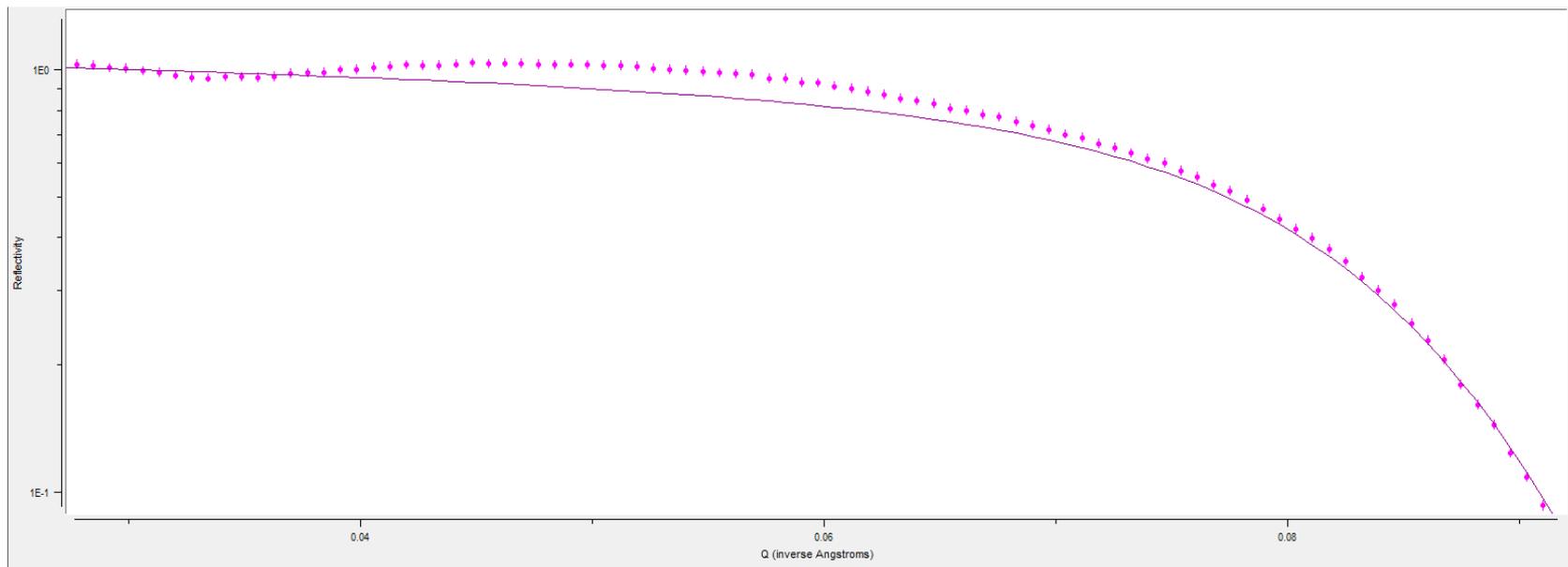
# Vacuum Correction



# Software Corrected Data - Vacuum Corrected Sample



# Vacuum Corrected Sample



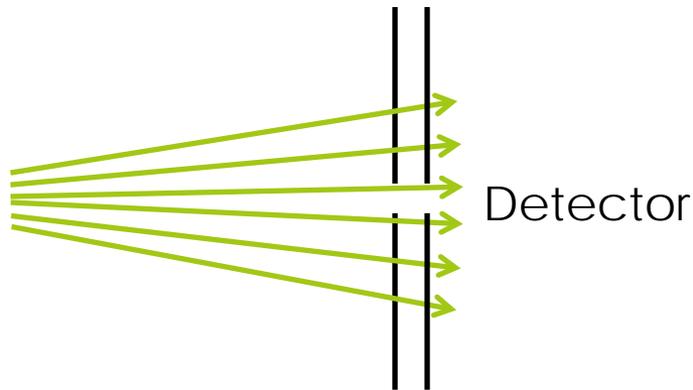


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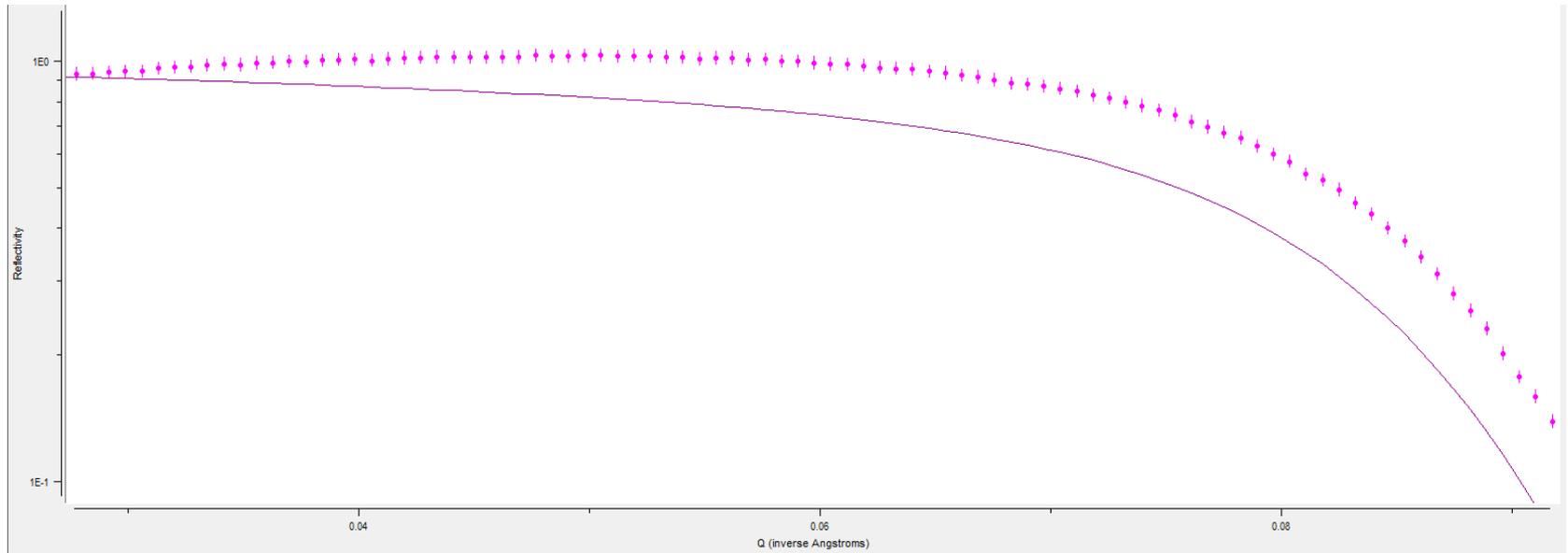
# Slit Modification

- In cases where the sample increases the spread of the beam, the detector can be opened up to read a larger spread of angles.

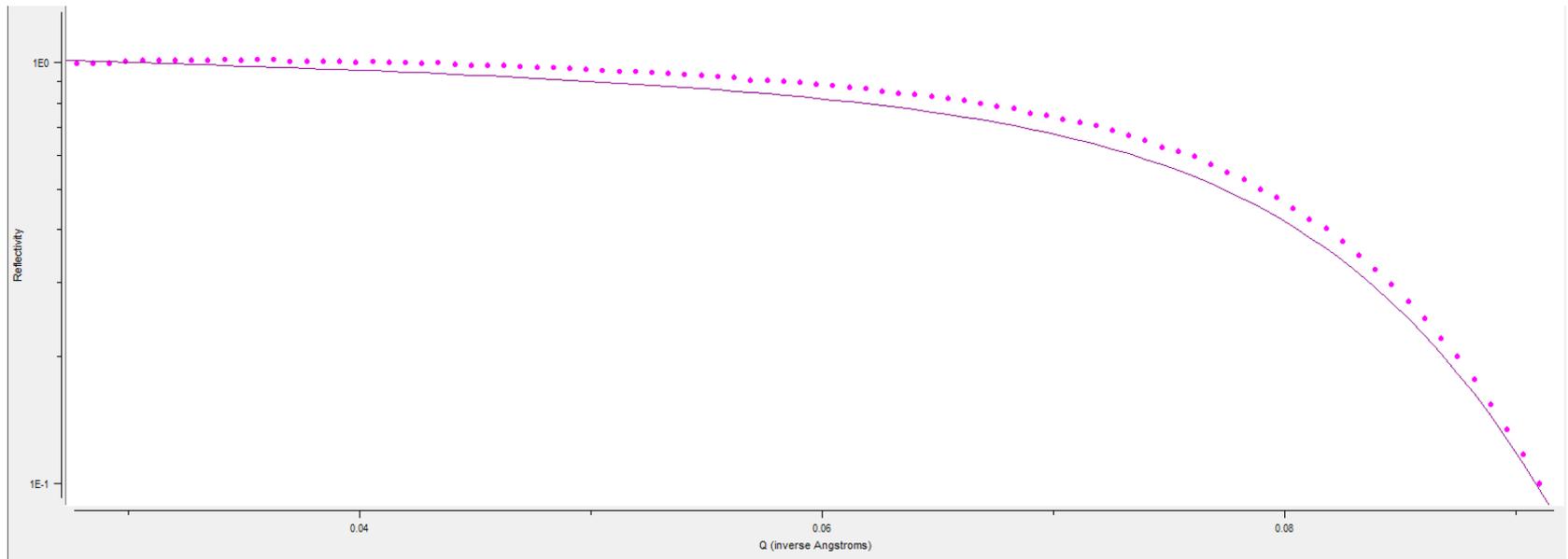




# Uncorrected Sample



# Sample Measured with Widened Slits





# Discussion

|                      | Pros                 | Cons                      |
|----------------------|----------------------|---------------------------|
| Software             | Very good correction | Many measurements         |
| Vacuum Sample Holder | Simple to implement  | Introduces extra features |
| Wide Slits           | Simple to implement  | Decreases resolution      |

# Future Work

- Machine different attachments to the vacuum system to allow for the use of samples of different sizes
- Investigate the source of the oscillation features in the vacuum corrected sample
- Detailed characterization of the x-ray beam for a better warp correction

# Acknowledgements

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