Single Photon Detection in SXR RIXS Experiments

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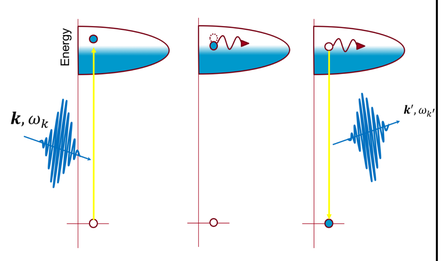
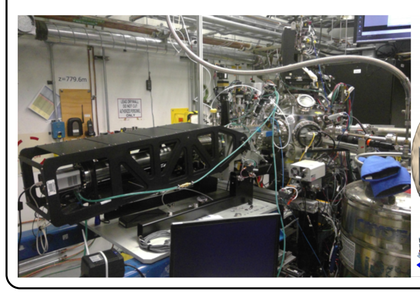
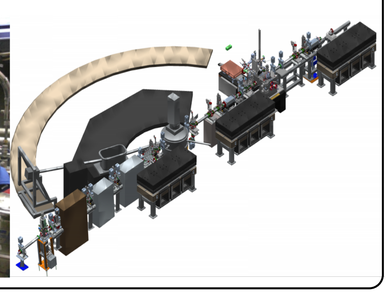
RIXS Experiment

- Andor Detector
- Measuring the charge order collective modes in $La_{2-x}Ba_xCuO_4$.
- Ultimately, we want a very robust analysis technique that can be replicated for future experiments at LCLS II.



Present & Future Applications



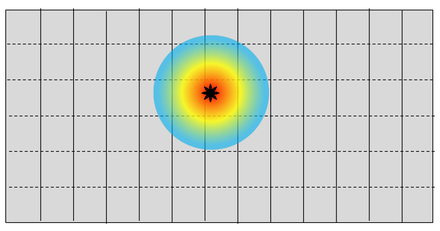


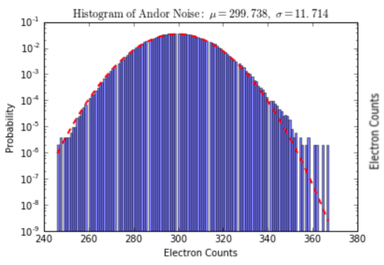
Goals of the Project

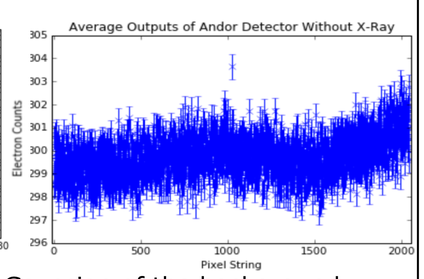
- Establish that spreading effects are present ✓
- Characterize signature of single photon collision events on CCD ✓
- Investigate whether or not we can use outputs to determine a photon collision's location at a sub pixel level

Andor Detector

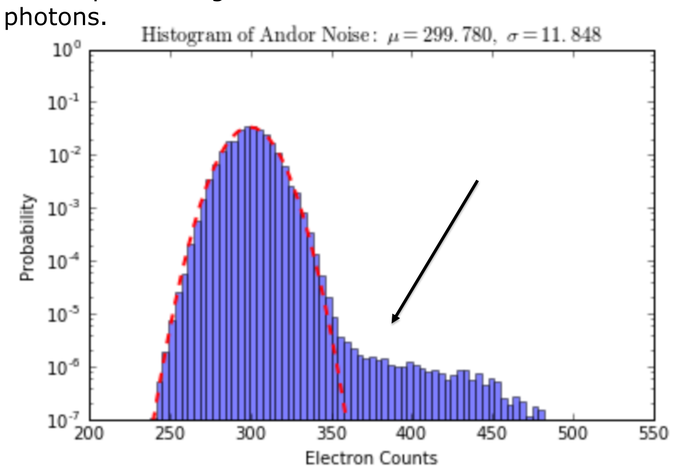
- Burst Readout Mode
- 1D Summation: 540x2048 pixel lens is summed vertically to become essentially 1x2048 pixel "strings"



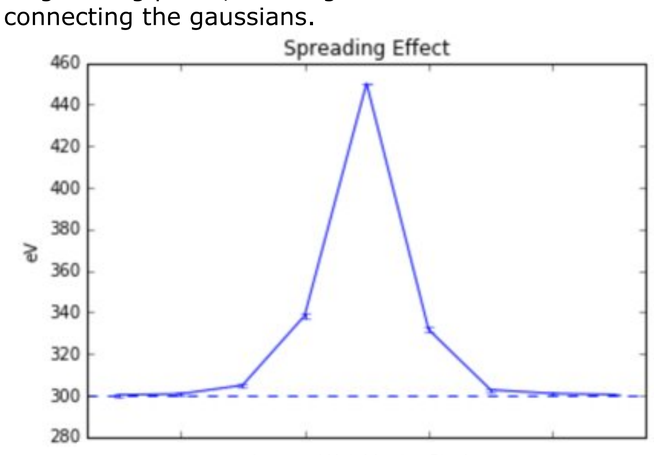




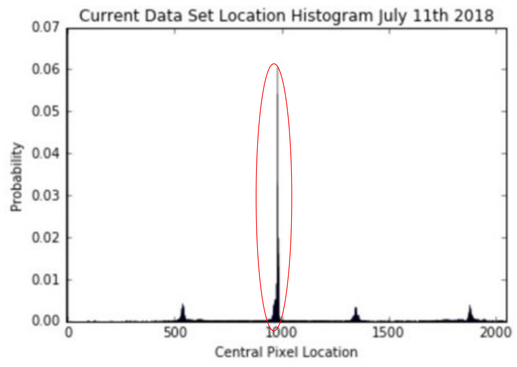
- Expect to see the (almost) Gaussian of the background noise as well as a Gaussian at a much higher counts value for the pixel strings that come in direct contact with emitted photons.



- However, electrons from the contact string spread to neighboring pixels, creating a lower count shoulder connecting the gaussians.



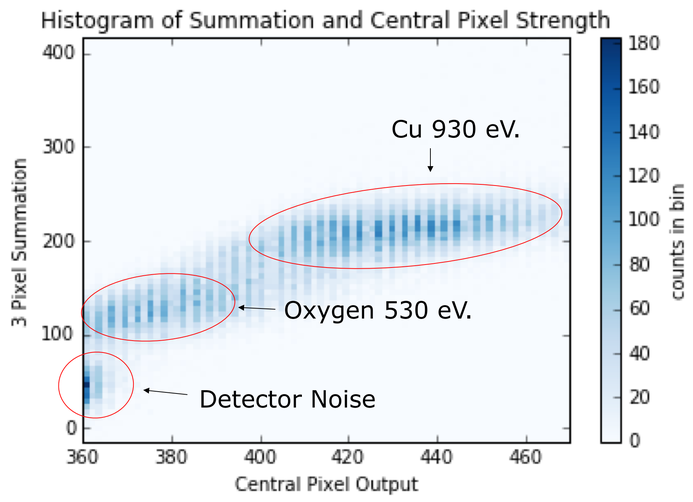
New Analysis Technique

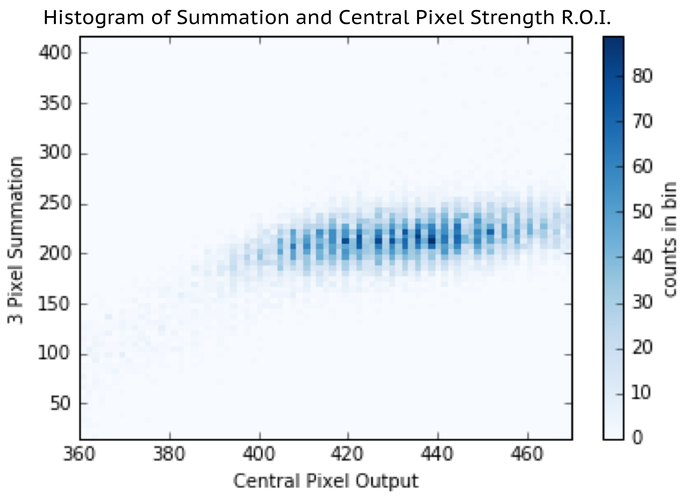


- Using the region of the camera where we expect to find real photon collisions, we can create some boundary conditions for certain parameters to eliminate noise. First, we need to determine how many neighboring pixel strings we are going to include.

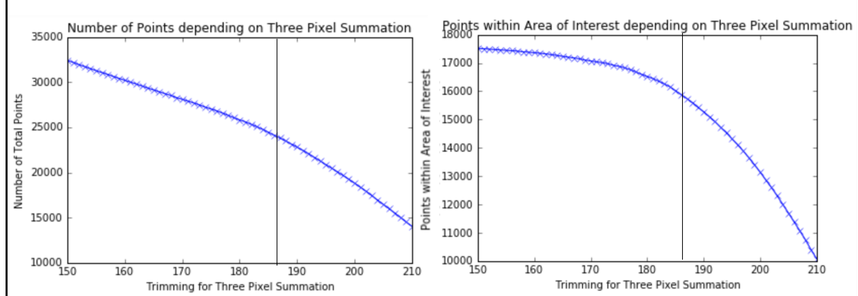
Neighboring Pixels	Summation Values	Sigma Values
3 Pixel Summation	213.208264389	20.5273312163
5 Pixel Summation	218.682897031	25.681679679
7 Pixel Summation	216.875981839	27.0936634033

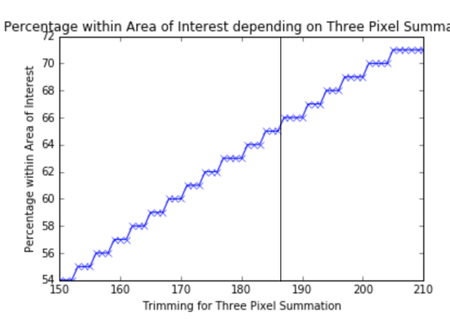
- Now that we've settled on a three pixel summation due to the lower sigma value, which indicates incorporating more neighboring pixels will increase the noise of the summation, we need to determine some reasonable boundary conditions for the total summation and central pixel strength.





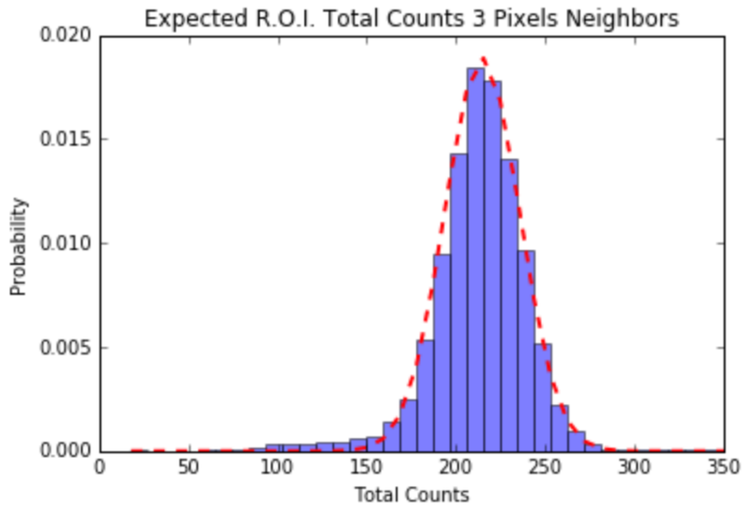
- While we could always just look at this 2D histogram and set the boundary conditions to trim everything else out, that could lead to throwing away collisions outside of our region.



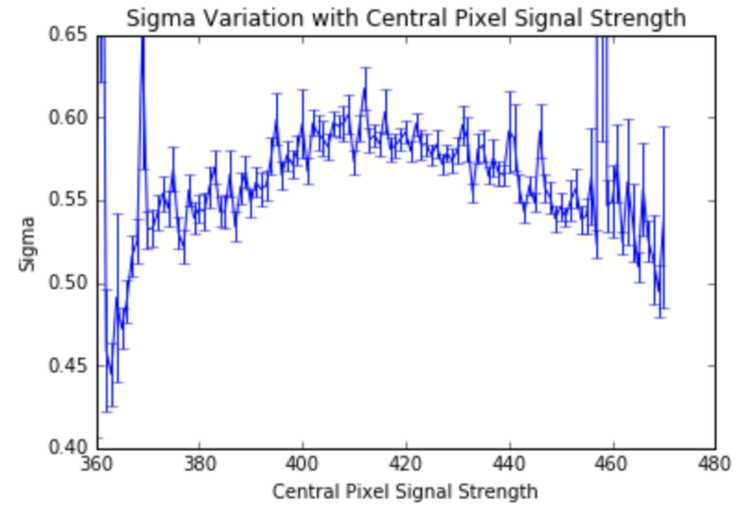


Fitting the Data

- While previous attempts at this analysis have centered around selecting a reasonable single pixel string output that signifies a photon collision, the new technique also concerns itself with a reasonable total count value.



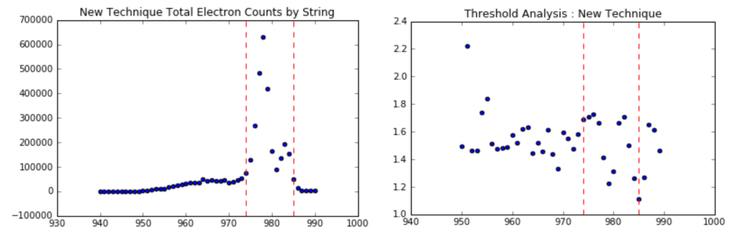
- However, the new technique still selects points by scanning for single string outputs before testing neighboring pixels. Therefore, we created justification for how we established reasonable single string outputs for selection.



Conclusions

Through introducing four new constraints, we were able to significantly reduce the number of events that were counted as photon collision events. Those constraints were:

- Neighboring pixels of the central pixel should produce a lower signal
- Neighboring signals should be checked for gamma signals
- The total number of counts should be within two sigma values of our mean summation value for our area of interest
- We should only consider neighboring pixels instead of the entire lens when summing total counts of a given collision



Plan on spending final week of project diving deeper into three final goals:

- Further analysis of trimmed points of new analysis
- Create thorough documentation of analysis steps
- Use data to develop photon collision simulator to test whether we can attain sub-pixel collision location precision

Acknowledgments

I'd like to thank Matteo Mitrano and Peter Abbamonte for giving me access to all of his data, I've greatly enjoyed the opportunity to get involved in some of the exciting research going on at LCLS as well as improve my Python ability. I'd also like to thank Chris O'Grady, Chuck Yoon, and Sion Zohar for being so helpful and guiding me through some of the challenges that arise when working in a new language. Additionally, I owe a great deal to Alan Fry, this was an incredible summer internship and I'm so grateful to everyone who put time and effort into making it possible. Finally, I'd like to thank the SXR group for their feedback throughout this project, and most importantly, Alex Reid specifically for guiding me through this entire project, it's been a pleasure working alongside you and I really can't express how much I gained through your mentorship.