

# Data Analysis Methods for Channeling Radiation at Fermilab's FAST Facility

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## Introduction

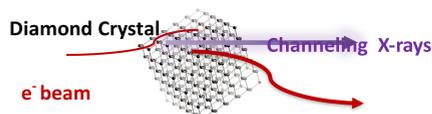
Electron beams can be used to produce X-rays through a process called channeling radiation (CR). The resultant X-rays could be as energetic as 140 keV. The Fermilab Accelerator Science and Technology (FAST) facility has the requirements needed to produce channeling radiation. This poster will discuss the data analysis and analysis methods used to diagnose possible issues during the experiment.

## Channeling Radiation

When a beam of relativistic electrons passes through a crystal, the electrons will scatter because of interactions of the particles in the beam and particles in the crystal. In most cases, bremsstrahlung is produced because of the deceleration of electrons.<sup>1</sup> However, if the beam:

1. Enters into a single crystal
2. Nears a crystallographic axis or plane
3. Enters a crystal of high symmetry

the “scattering” of the electrons becomes more coherent, and the electromagnetic radiation it emits is channeling radiation.<sup>3</sup>



This channeling radiation can be:

- Directed
- Intense (dependent on beam energy)
- Tunable

The X-rays produced by channeling radiation can be used for many industries, ranging from atomic physics research to medical applications.

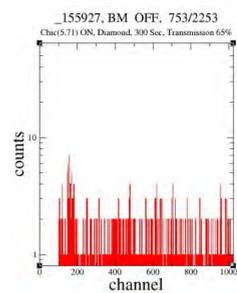
## FAST

According to FAST website, “The Fermilab Accelerator Science and Technology (FAST) currently under construction at Fermilab will soon enable a broad range of beam-based experiments to study fundamental limitations to beam intensity and to develop transformative approaches to particle-beam generation, acceleration and manipulation.”

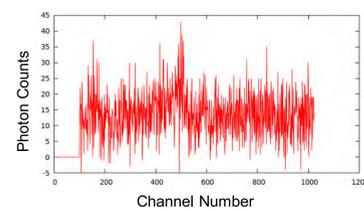


All data for the channeling radiation experiment referred to in this poster has been obtained at FAST.

## Dark Current



A large amount of background noise caused by dark current was recorded. As the graph on the left illustrates, even when the electron beam is turned off, X-ray photons are produced. Studies of the dark current spectra were done to pinpoint the exact source of the background noise.



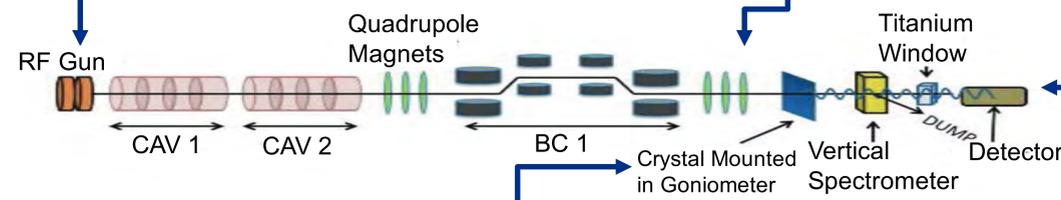
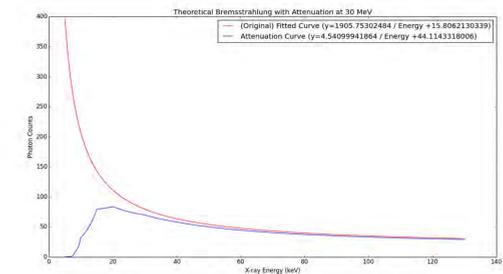
The graph on the left was produced by subtracting two different spectra. There appears to be a clear spike on the channel that corresponds to an energy level of 74 keV; 74 keV corresponds to the characteristic energy of steel.

## Attenuation

The signal of the X-ray photons is reduced through attenuation as it travels through air.

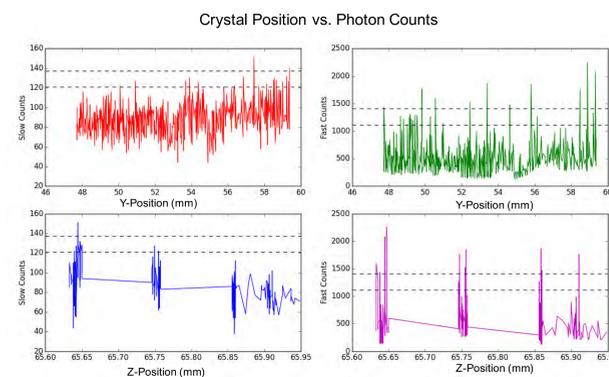
$$\frac{I_T(E)}{I_0(E)} = \exp[-L/L_{abs}] \quad L_{abs} = \frac{1}{\mu\rho}$$

Attenuation was incorporated into theoretical models<sup>2</sup> using the above equations. While attenuation accounted for less photons produced than expected, there were many other reasons for photon detection loss. The graph below illustrates how attenuation affects X-ray photon spectra.



## Crystal Position

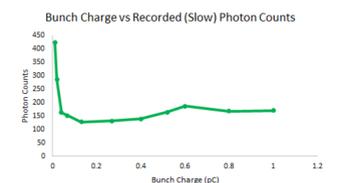
The orientation and position of the diamond crystal is an important aspect of channeling radiation. A script was produced that would minutely change the position of the crystal and then record the photon spectra produced by such an orientation. While the exact positioning has not yet been determined, one can tell that certain positions yield more photon counts than others.



In the above graph, y and z positions represent the pitch and yaw, respectively, of the crystal. In this study, the more photons produced, the better.

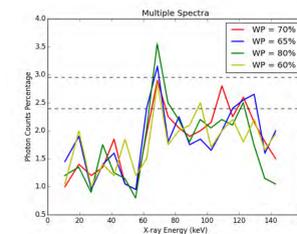
## Detector Saturation

Theoretically, as the beam charge increases, the amount of resultant photons produced should also increase. As illustrated by the graph on the right, that was not the case.



The photons produced by either CR or dark current are arriving at a higher resolution time than the detector system allows for. The detector therefore does not count a majority of X-ray photons. In order to account for detector pileup, the electron bunch charge has been reduced to ~0.01 pC. The figure below illustrates consistent data after the bunch charge

has been reduced. Each line represents a spectra around 0.005 pC. This particular study investigated how to reduce bunch charge, particularly by altering wave plate percentage.



## Citations

- [1] B. Azadegan, *Comp. Phys. Comm.*, 184, 1064 (2013).
- [2] J. Hyun, *Proceedings of IPAC 2016* (2016).
- [3] D. Mihalcea et al., *Proc. IPAC15*, 95 (2015).

## Acknowledgements

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