Bremsstrahlung Measurement on the Superconducting Source for Ions (SuSI)

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Abstract

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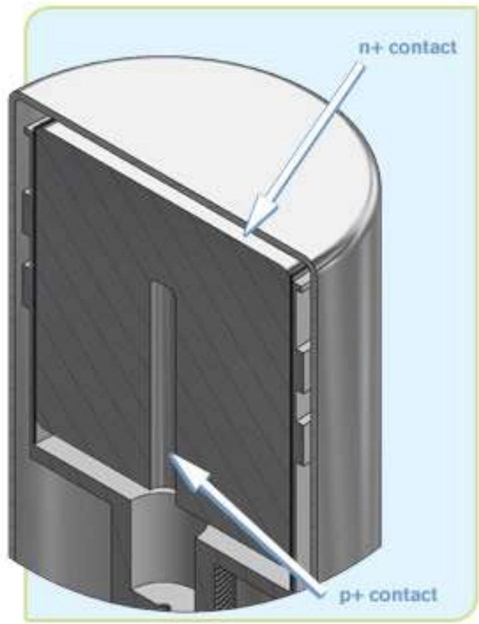
Electron Cyclotron Resonance (ECR) ion sources are the choice of injector for many heavy ion accelerator facilities worldwide that are currently in operation, under construction, or proposed. Driven by demands of the scientific programs at those facilities, more particle current and at higher charge states are required from ECR ion sources. To meet these demands, fully superconducting sources with higher magnetic confinement fields operating at increased microwave frequencies are being developed. Technical design of these sources requires an understanding of the x-ray loading from the plasma into the cryostat. By measuring the x-ray spectrum from the plasma an estimate can be made for the expected heat load for the next generation of ECR ion sources. We aim to investigate the hot electron population (larger than 50 keV) residing in an ECR plasma over the next several years. In conjunction with ion confinement time measurements we will be able to better understand microwave heating at different frequencies and develop diagnostics to characterize ECR ion source plasma confinement.

This poster presents axial x-ray measurements on SuSI using a set-up that follows closely that of T. Ropponen *et. Al.* [1] to measure the hot electron population. Preliminary results from SuSI at 18 and 24 GHz heating frequencies as well as a description of our new data acquisition system will be presented.

Bremsstrahlung Measurement with a Germanium Detector

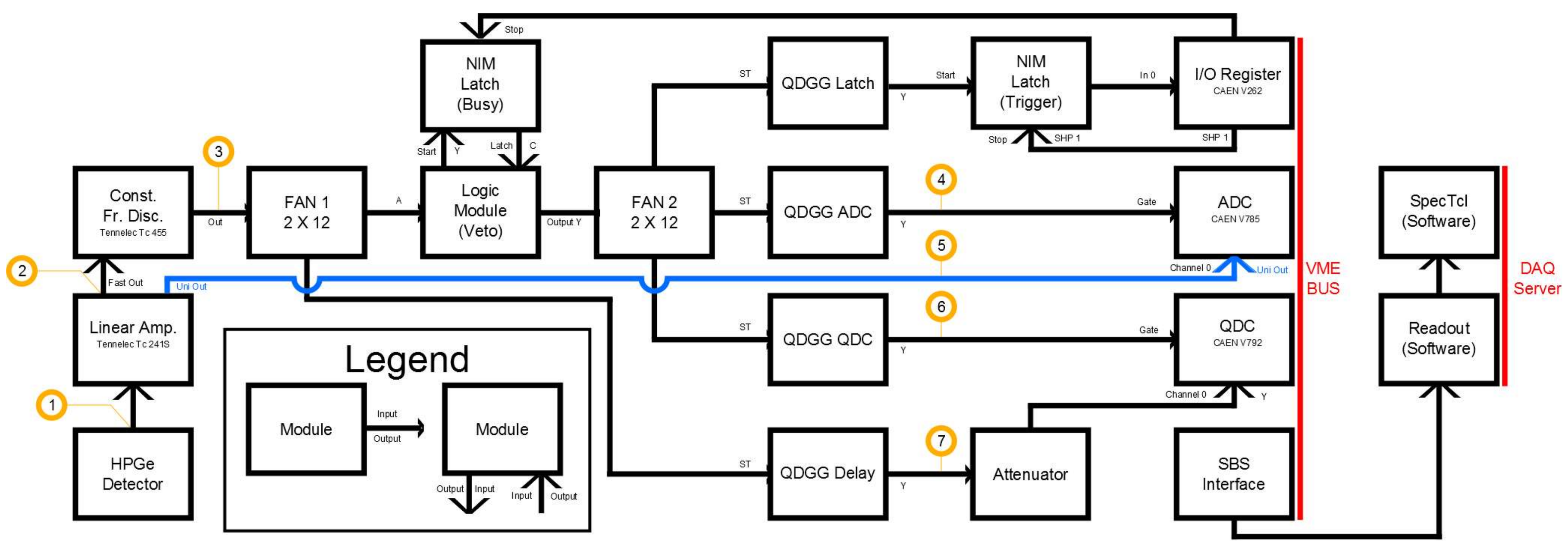


Radiation Detection

High Purity Germanium Detector (HPGe) is a thick crystal diode used to detect gamma radiation. Typically of coaxial design, the diode is then cooled to liquid nitrogen temperatures and reversed biased to deplete the volume of electrons. Photons interact with the crystal volume and create ion pairs proportional to the energy deposited. These charges then drift through the volume where they are collected on the electrode surfaces.

A preamplifier collects the charge and provides a voltage response that may be routed to a data acquisition system.

On Left: *A CAD drawing of a Canberra coaxial HPGe detector [2].*

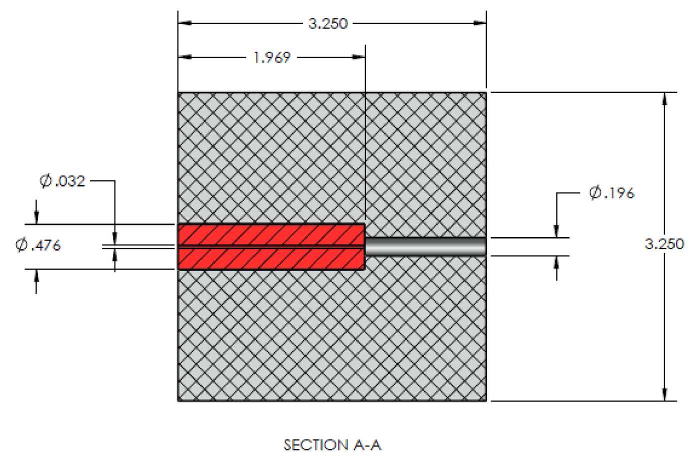


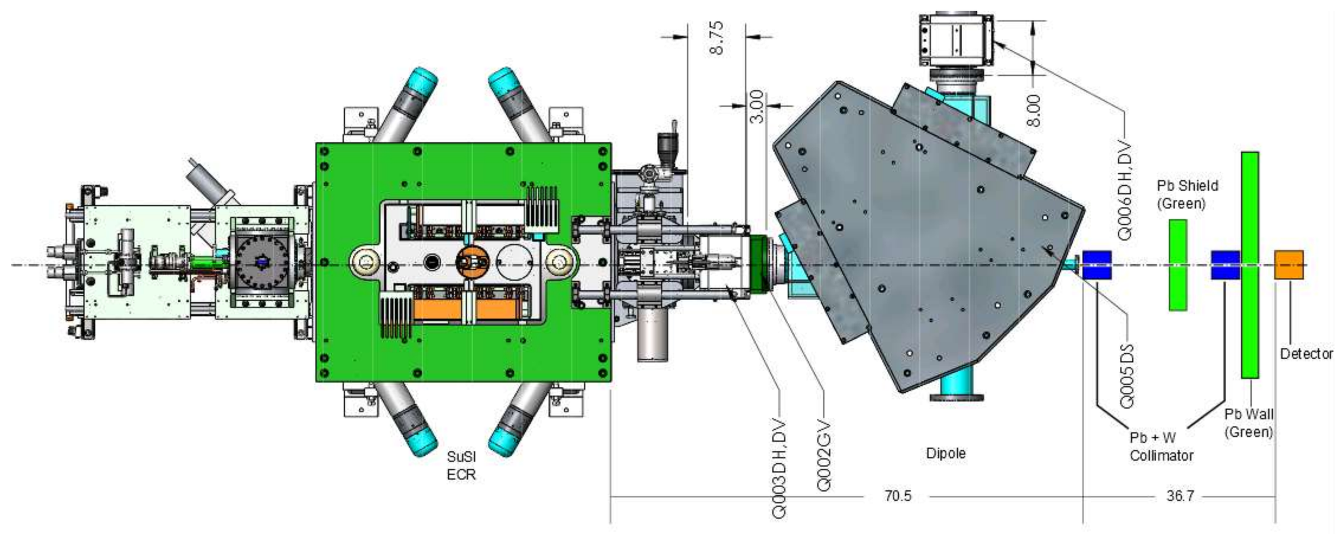
Above: *Block diagram of the data acquisition system for the HPGe detector. The blue Gaussian like signal (5) is used to resolve energy by measurement of the peak voltage when the logic gate (4) is true. The initial timing signal (2) is delayed so it occurs coincidentally with (5) and is fed into a charge integrator which can then count how many events arrive when (6) is true.*

Geometry and First Measurements

Experiment Geometry

The SuSI ECR ion source provides heavy, multiply charged ion beams for the Coupled Cyclotron Facility (CCF). Hot electrons in the plasma and in order to prevent saturation of the HPGe detector we place the detector several meters from the source. Lead and tungsten collimation is used to further reduce the observable solid angle.

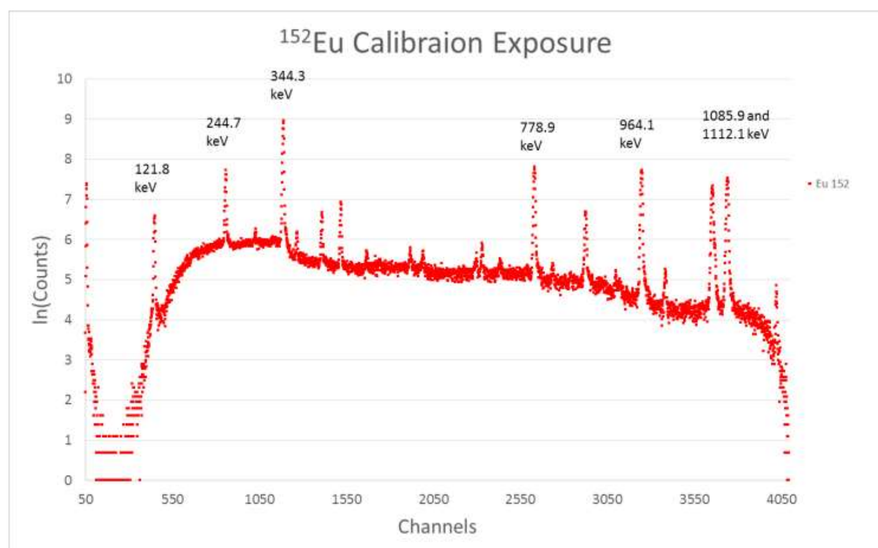


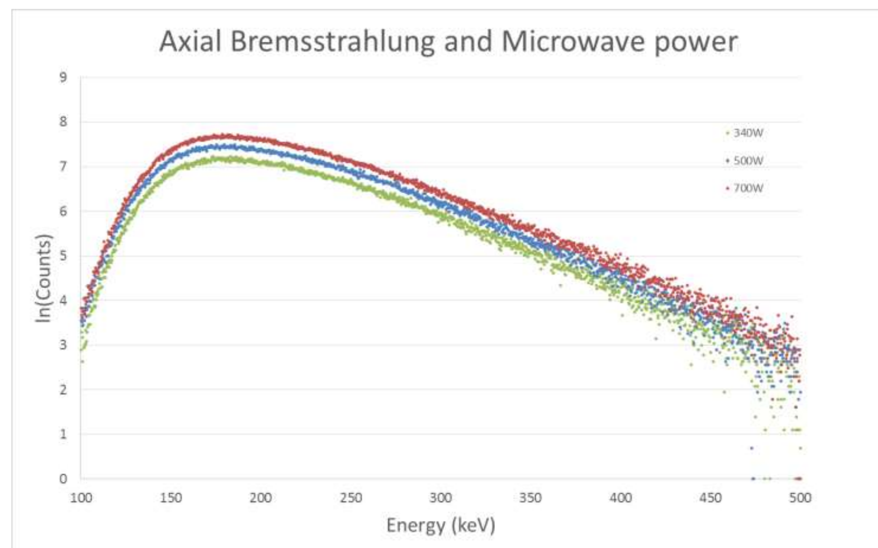


Above: A thick lead collimator cube with cylindrical tungsten insert to reduce the solid angle observed by the detector.

On Left: The SuSI ECR ion source in reference to the detector and collimation system (not to scale).

Calibration with ^{152}Eu and preliminary results on SuSI





On Left: *Europium 152 with distinct spectral lines that allow for calibration of channels to energies.*
On Right: Bremsstrahlung as measured from SuSI for three different microwave powers. For each setting the slope and terminal energy of approximately 475 keV do not change significantly.

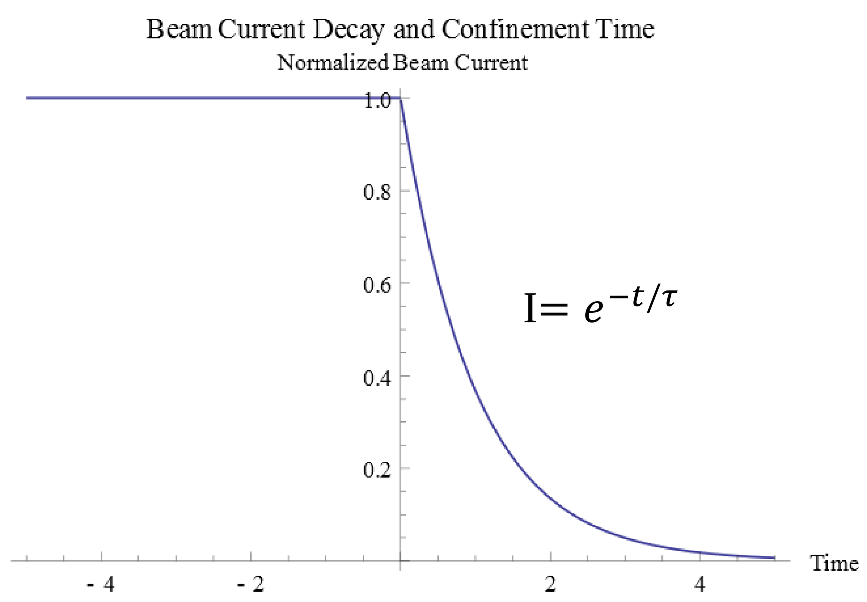
Future Plans and Continued Research

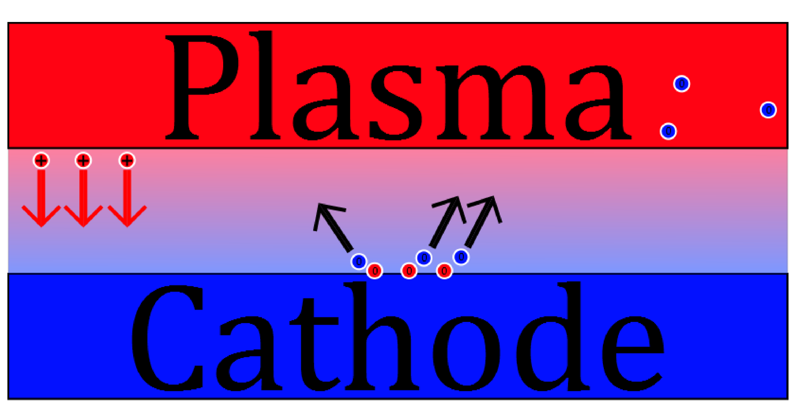
Ion Confinement Time

We can investigate the ion confinement time by observing the decay of beam current per plasma species upon the fast removal of the element's neutral supply. Ion confinement times are estimated in [3] to be several milliseconds in length, and therefore we require control on neutral supply to at least microsecond timescales. We propose to sustain a plasma from the gaseous elements and then introduce a solid material via sputtering.

Fast Sputtering

Sputtering is a process that removes a solid material by bombardment by massive ions. We use this process because it is compact and the voltage differential may be neutralized in microseconds.





Above: An idealized simulation of what we expect to observe from a fast cessation in neutral supply.

On Left: Cartoon of sputtering process wherein ions within sheath accelerate into the cathode ejecting material into the plasma.

On Right: *A CW sputter system designed for uranium. We may use this kind of design as a starting point for microsecond rise time high voltage pulses.*

Summary

An x-ray detection set-up on SuSI has been assembled using a HPGe detector employing a well defined pileup rejection method. First spectra demonstrates proof of principle, but a more systematic measurement campaign needs to be performed to extract useful relationships between machine parameters and bremsstrahlung spectra. We are designing a fast sputter probe to analyze the ion confinement time and measure systematically its relationship to magnetic field and microwave frequency. We may then couple x-ray and confinement time measurements for a holistic understanding of this kind of ECR discharge.

REFERENCES:

[1] T. Ropponen, D. Cole, G. Machicoane, *et. Al.* Proceedings of ECRIS2010, Grenoble, France, WECOAK04 (2010)
[2] Canberra, "Standard Electrode Coaxial Ge Detectors" WWW Document, (2015)
[3] R. Harkewicz, P. J. Billquist, R. C. Pardo, "Recent Developments at Argonne National Laboratory and the New ATLAS 14 GHz ECRIS Project", ECRIS (1995)

ACKNOWLEDGEMENTS:

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