Utilizing Python to Prepare the VENUS Ion Source for Machine Learning*

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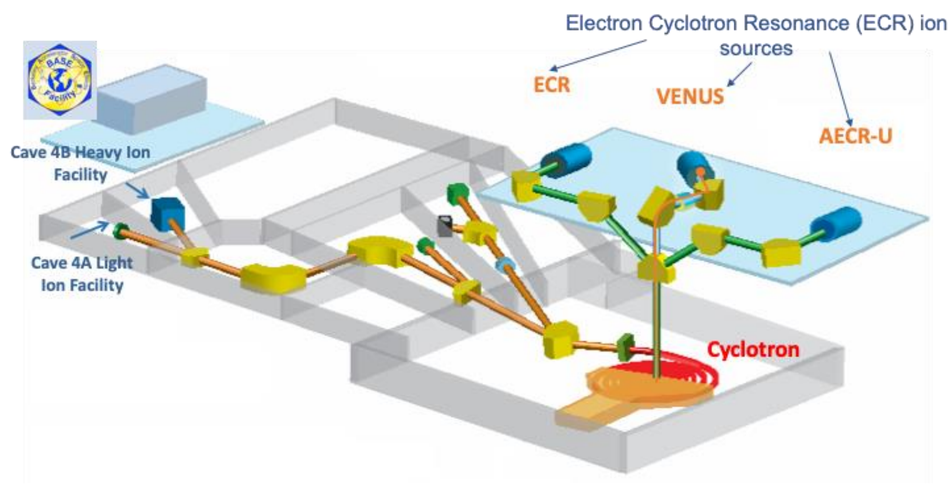
The fully-superconducting electron cyclotron resonance (ECR) ion source VENUS is one of the world's two highest-performing ECR ion sources, and a copy of this source will soon be used to produce ion beams at FRIB. The tuning and optimization of ECR ion sources is time consuming and there are few detailed theoretical models to guide this work. To aid in this process, we are working toward utilizing machine learning to both efficiently optimize VENUS and reliably maintain its stability for long campaigns. We have created a Python library to interface with the programmable logic controller (PLC) in order to operate VENUS and collect and store source and beam data. We will discuss the design and safety considerations that went into creating this library, the implementation of the library, and its some of the capabilities it enables.

ECR Ion Sources of the 88-Inch Cyclotron



Venus Overview

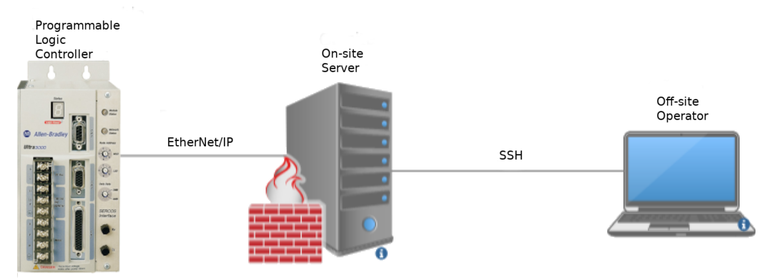
VENUS is a next generation superconducting ion source at Lawrence Berkeley National Laboratory that is used to feed the 88-inch Cyclotron with high-current and charged state ions to be accelerated.

ECR Control Parameters

VENUS has over 20 variables that can be written to and over 80 diagnostic variables that can be read.

Design Considerations

1. **Safety + Security**
   a. **Prevents concurrent use**
   b. **Employs authentication**
   c. **Manual override**
   d. **Restrict modification of hidden variables**
   e. **Complies with existing safety code**
2. **Usability**
   a. **Easy to read code**
   b. **Abstract interface**
   c. **Highly extensible**



Network Diagram

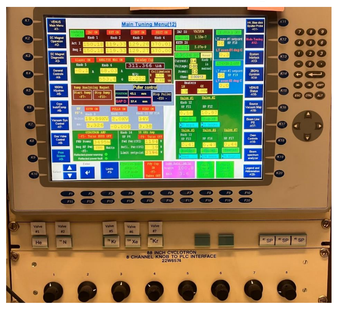
Code Overview

PLC Interface

- **Read variables**
  - ✓ **Example: "read the injection pressure (in Millibar)"**
- **Write variables**
  - ✓ **Example: "set the injection solenoid current to 110 Amps"**
- **Meta variables**
  - ✓ **Abstract operations that are used often enough to get a function**
  - ✓ **Example: "get a charge state distribution from this M/Q to this M/Q"**

Database Interface

- ✓ **Used to save all data collected from VENUS**
- ✓ **Allows for future data analysis**



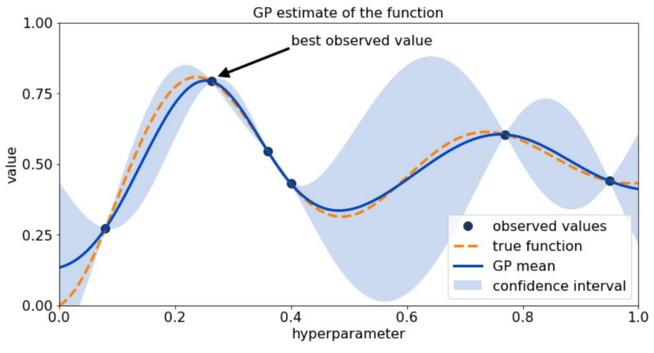
PanelView Human-Computer Interface

Current Work

- **Logging**
  - ✓ **Constantly log VENUS state**
- **Testing Hypothesis**
  - ✓ **Verifying how magnetic fields would influence beam current**
- **PLC modification testing**
  - ✓ **Test setting gas pressure directly instead of the rate of gas that goes into VENUS**
  - ✓ **Experiment with different control algorithms for setting solenoid magnet currents**

Future Work

- **Analyze Collected Data**
  - ✓ **We have months of second-by-second data which we are in the process of analyzing**
- **Machine Learning**
  - ✓ **Applying Machine Learning techniques to the data or directly to the PLC interface**
  - ✓ **Implementing Bayesian Optimization**



https://cds.cern.ch/record/2702355/plots

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88-Inch Cyclotron