Spallation Neutron Source RF Systems

Tom Hardek

Mark Crofford

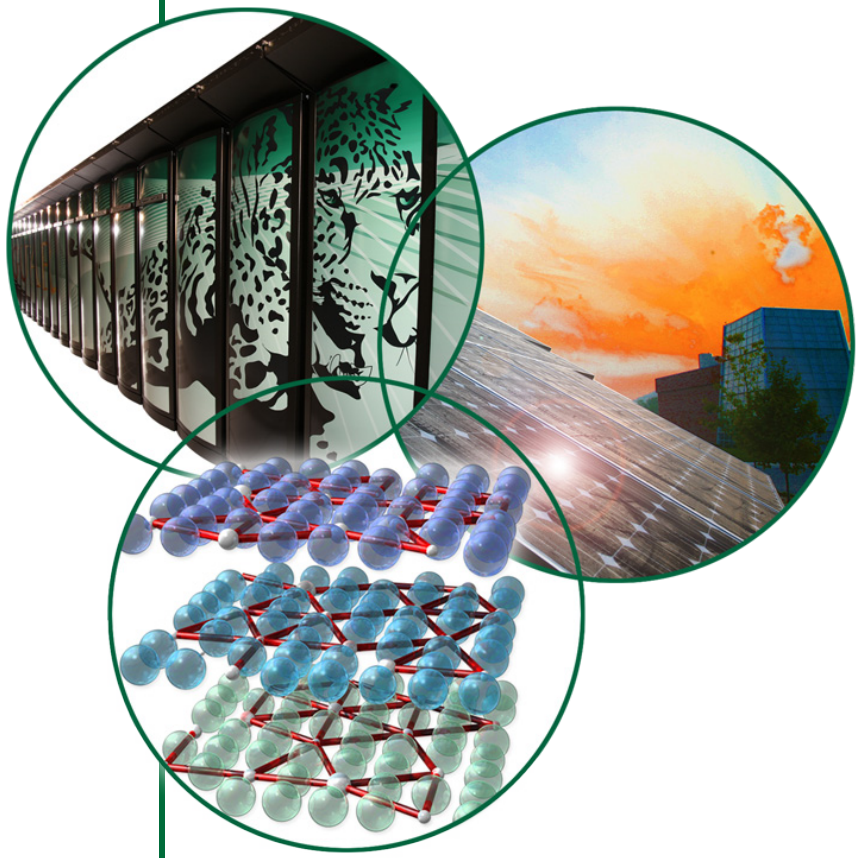
Mark Middendorf

Maurice Piller

Yoon Kang

Sung-Woo Lee

Alexandre Vassioutchenko



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

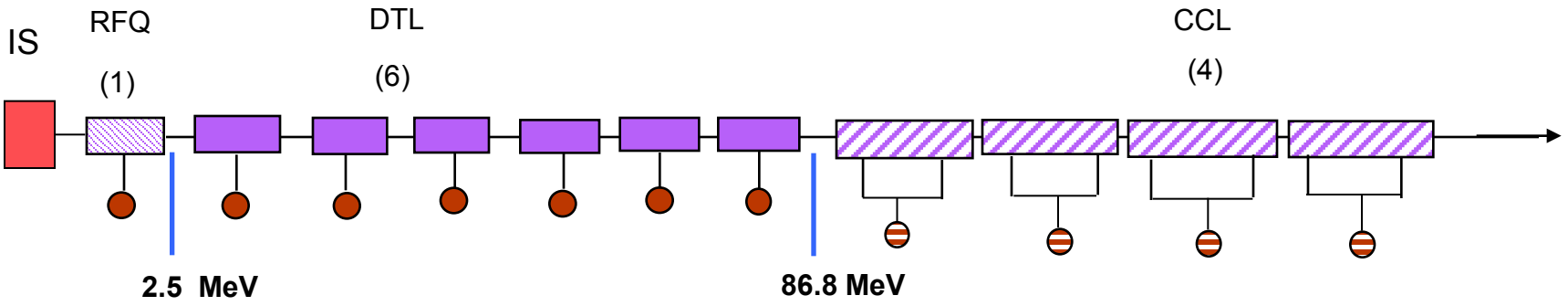
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

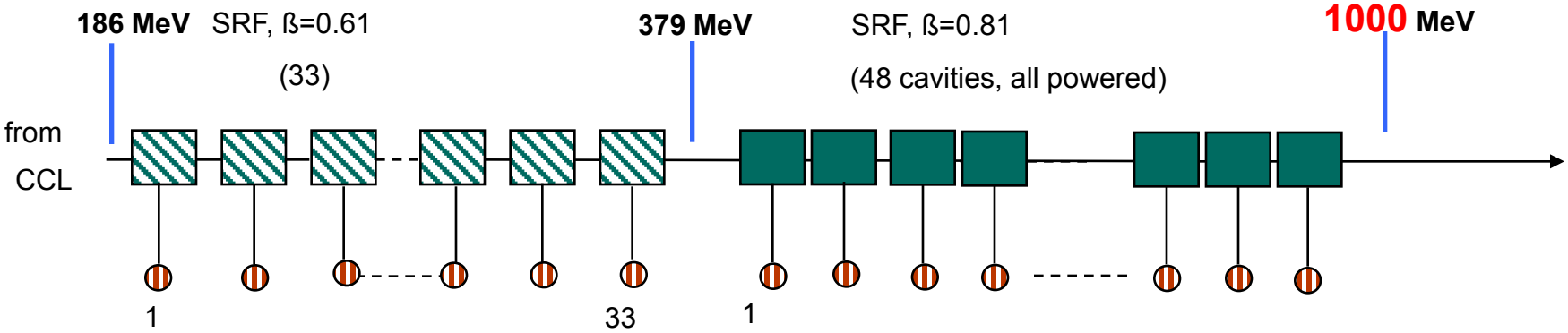
Outline

- SNS RF Systems Review
- Overview of Performance
- RF Related Issues addressed over the past several Years
- A Look into the Future

Layout of Linac RF Modules

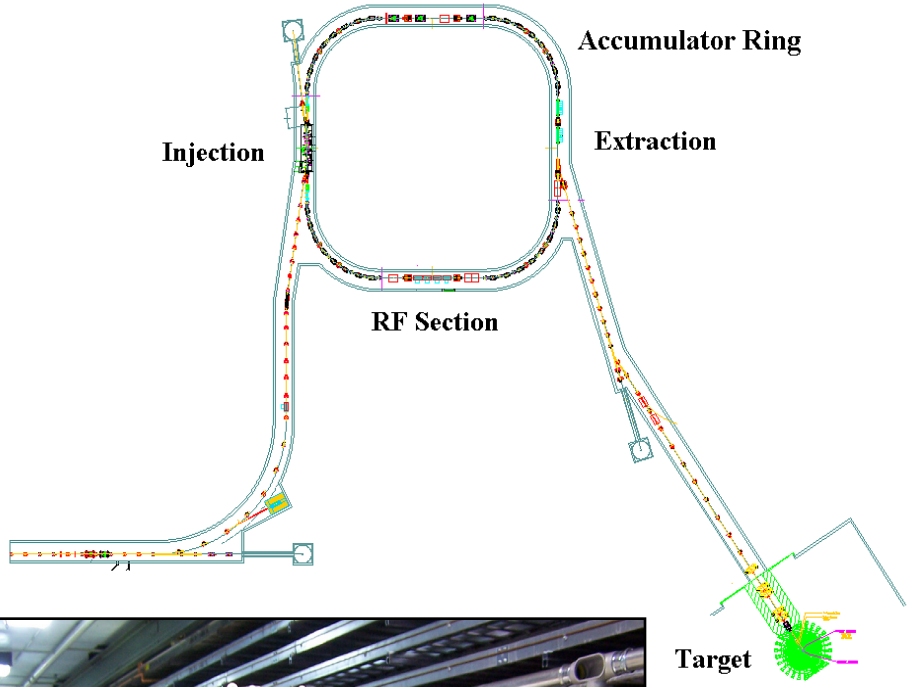
402.5 MHz, 2.5 MW klystron	7 Transmitter	3 Modulators
805 MHz, 5 MW klystron	4 Transmitter	4 Modulators
805 MHz, 0.55 MW klystron	14 Transmitter	8 Modulators





Accumulator Ring

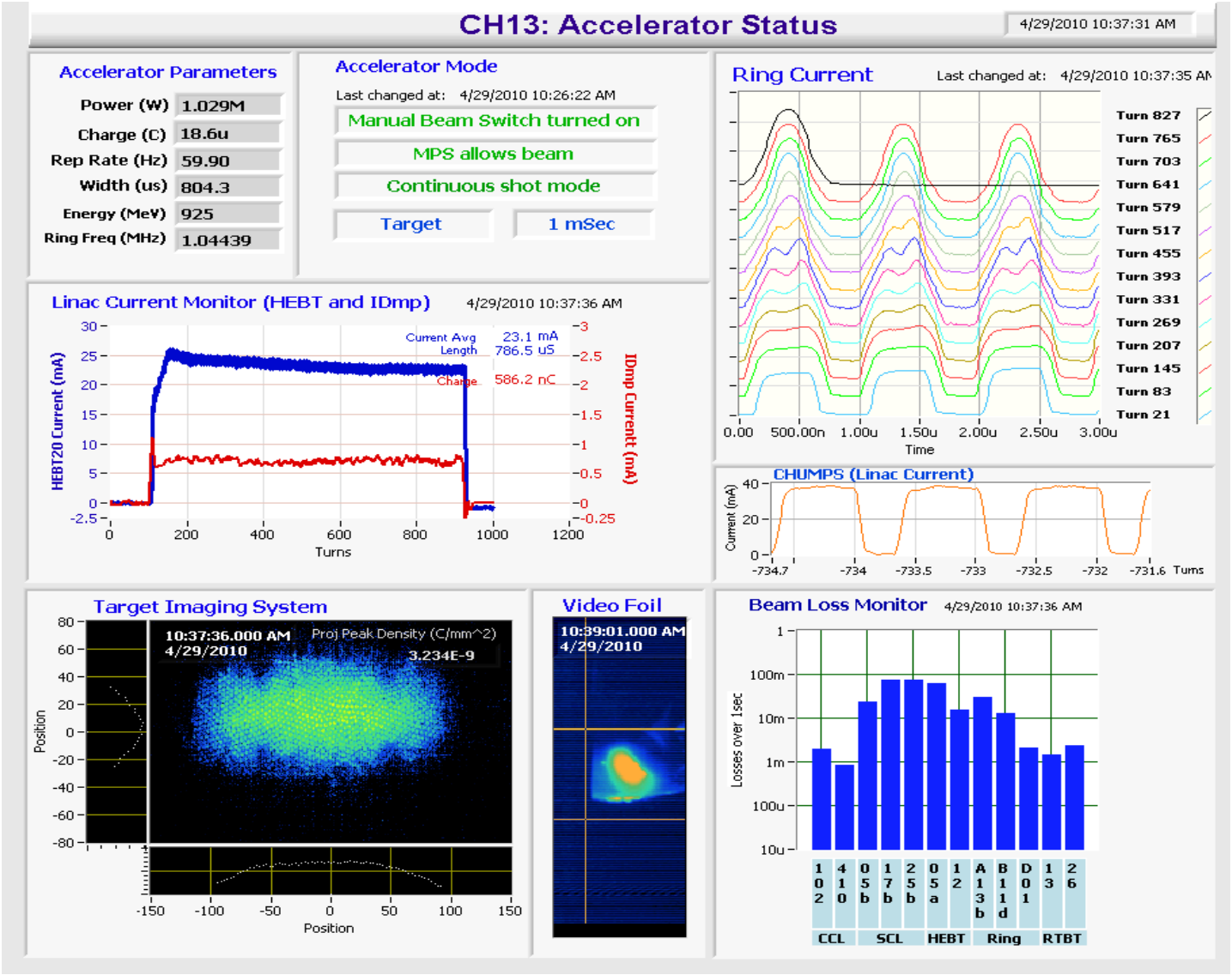
- Ring RF
  - 4 Bunching Cavity/Amplifier stations
    - Ferrite loaded (Phillips 4M2)
    - Cavity Bias provides dynamic tuning
    - Beam pipe and outer housing used for bias.
  - 2 bunching gaps per cavity
  - 3 Buncher Cavities operate at the revolution frequency 1.05 MHz
    - Maintain a gap to allow the extraction kickers adequate time to reach full field.
  - 1 Cavity operates at the 2nd harmonic 2.1 MHz
    - Reduce the peak beam current to minimize the possibility of exciting instabilities.
  - All cavities and amplifiers are the same.
    - Resonating capacity reduced for the 2nd harmonic cavity allowing use of the same structure.



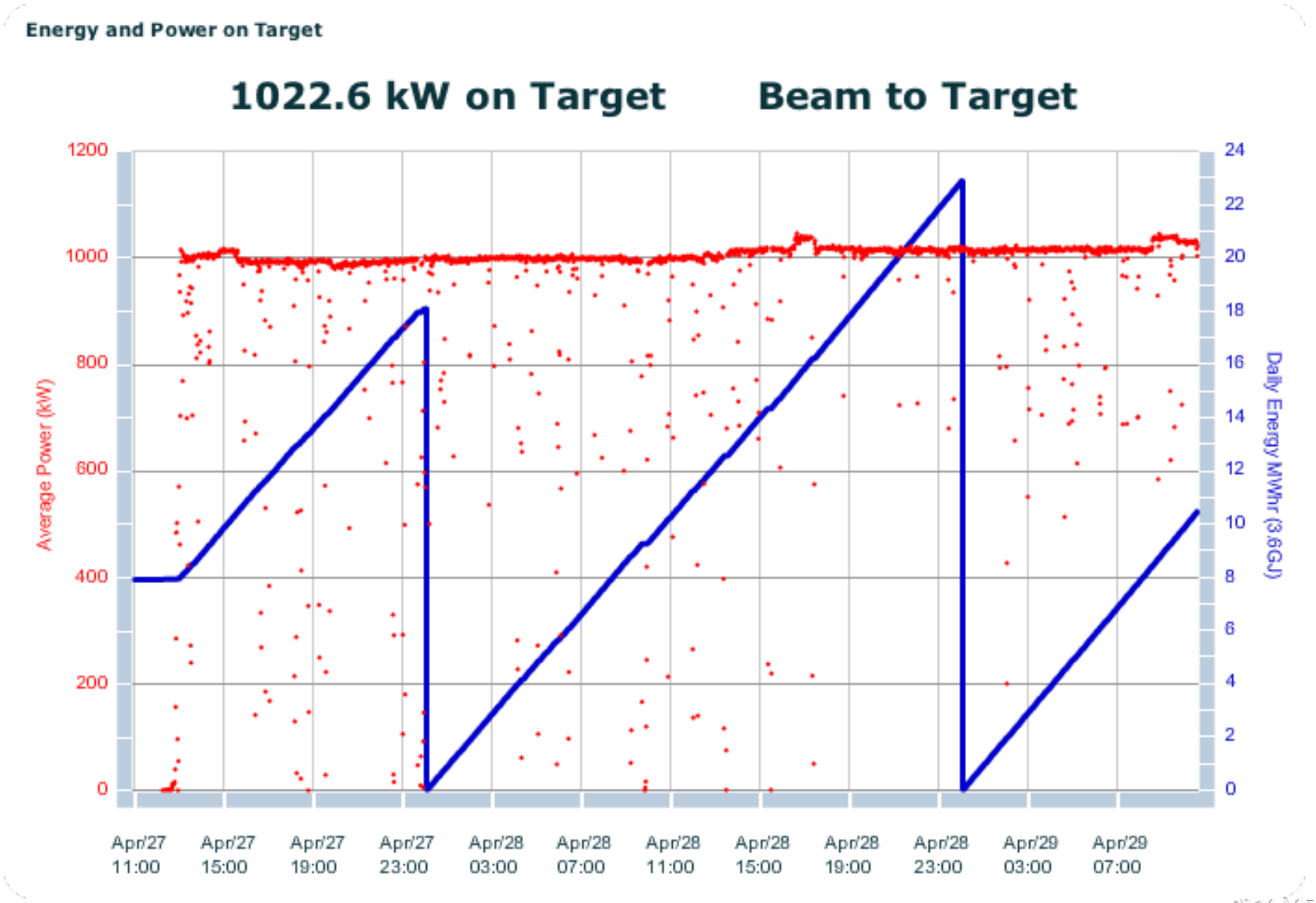
Performance Overview

- RF Systems/Structures running very well
  - Los Alamos deserves much credit for delivering a reliable RF system and warm Linac
  - JLab deserves much credit for delivering an excellent Superconducting Linac
  - Berkley deserves credit for the RFQ, Ion Source and front end systems
  - Brookhaven deserves credit for delivering a reliable hands-off Ring RF system
- Delivering production neutrons since April 2006
- Reached 1 MW on September 18, 2009
- Operating at greater than 85% reliability (88% goal this year)
- Run at over 90% reliability for extended periods

Overall Operating Parameters



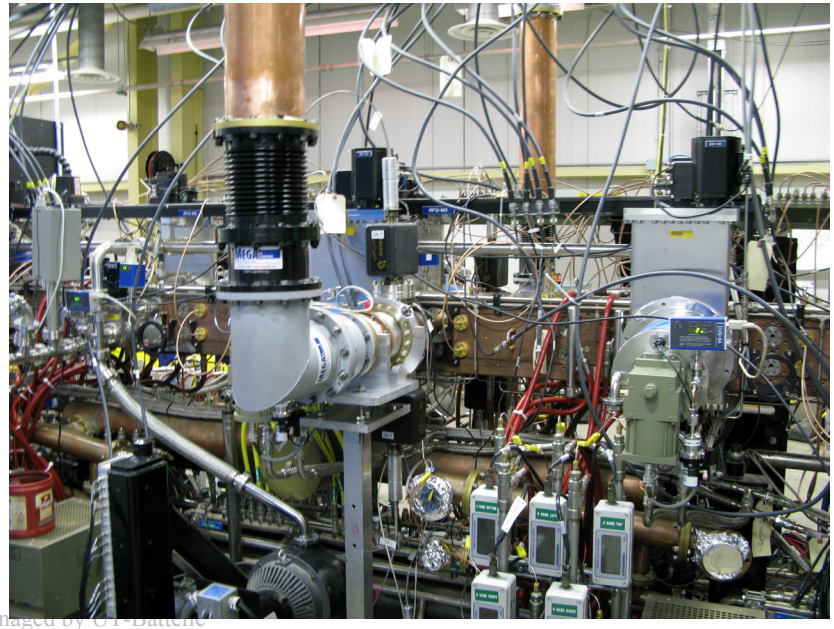
Extended Operation at 1 MW



Improvements to the RF Systems

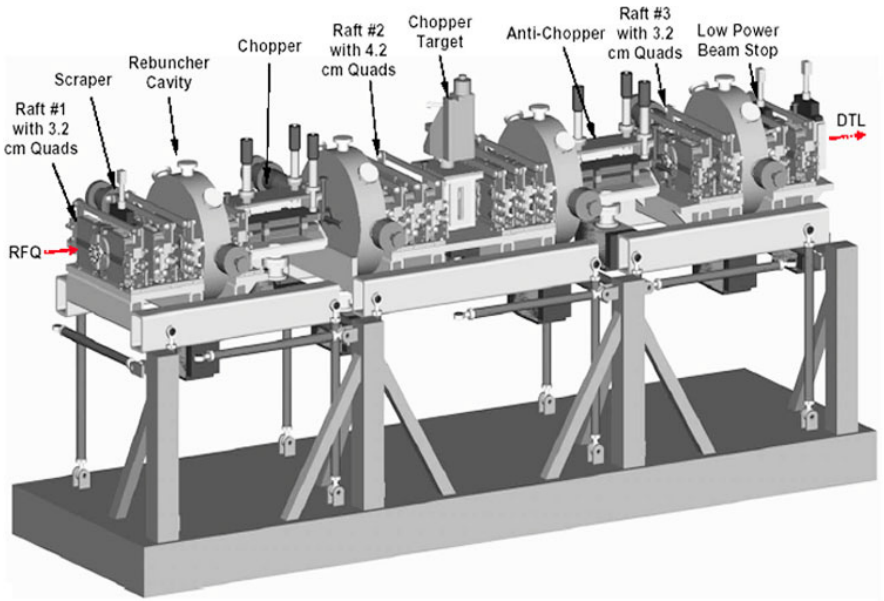
Ion Source & RFQ

- Developed HV Isolation Transformer
  - Allows 2 MHz Amplifier to operate at ground potential
  - Plan to replace the present gridded tube amplifiers with 120 kW solid state units operating at ground potential.
  - Have 2 each 120 kW Solid State amplifiers in hand



- Replaced original RFQ Drive Couplers
  - Original couplers were hard to balance leaving the power split unequal
  - With the unequal power split there was concern that a coupler could be damaged.
  - Used similar design as SCL Couplers
  - Replaced 8, 100kW couplers with 2, 600 kW couplers
  - RFQ runs at about 700 kW

Medium Energy Beam Transport (MEBT)



- 4 Rebuncher Cavities
  - 20 kW each
- Includes
  - MEBT Chopper
  - Quadrupole magnets
  - Scraper
  - Beam Stop

- Original Amplifiers were cavity tuned gridded-tube amplifiers
  - Difficult to tune and not reliable
  - Replaced with Solid State
    - 402.5 MHz
    - 25 kW
    - 1.2 msec pulse length
    - 4 operational amplifiers + 1 spare
    - Spare can be remotely switched to any cavity

Extra Converter Modulator

- Added Extra Modulator
  - Original design called for 11 or 12 klystrons/modulator
  - Actual modulators could only run at 69 kV due to an output current limit
  - Klystrons designed to run at 75 kV
  - Extra modulator allows 10 klystrons/modulator and allows operation at 75 kV

Low Level RF

- Developed 8 channel power meter
  - Will allow monitoring more coupler ports
  - Useful to record klystron perveance
  - Used to monitor the individual amplifier units of the new MEBT amplifiers
- Added Picoampere-meters
  - Original cold cathode vacuum gauges have trouble staying alive
  - We use an electron probe as an additional interlock
- Have an updated Field Control Module (FCM) Design
  - Observed beam loss associated with small phase shifts in FCM
  - Traced loss to klystron gallery temperature changes
  - Removed Analog Front End section and moved it to temperature compensated down-converter chassis.
  - Gained factor of 10 in temperature stability
- Added a workable Quench detection feature to the software.
- Replaced irradiated sections of arc detector glass optical fiber with easily replaceable plastic optical fiber jumpers
- Implemented a fiber test system
- Added slow pulse width and chiller temperature feedback loops to RFQ control page

A Look Into the Future

- Power Upgrade (PUP)
  - Add 36 more SCL Cavities, Klystrons and LLRF Systems
- Intensity upgrade
  - Requires more RF Power
  - Will replace some klystrons and upgrade HVCMs
  - Will need to Process some of our SCL Cryo-modules for higher accelerating field in cavities
- Second Target Station (Currently on-hold)
- Existing LLRF modules have obsolete components
  - Need to be working on next generation system
- Ring LLRF
  - Want to replace existing hardware and software with a version more compatible with our Linac systems

Summary

- SNS reached 1 MW in mid September as promised to DOE
- Presently operate with better than 85% reliability
  - Ultimate goal is 95%
  - We have identified major sources of downtime and are addressing them
- Ion Source amplifier operating at ground potential.
- MEBT RF Upgrade is operational with only minor cleanup work remaining.
- SCL RF Power limitation was resolved by adding an extra converter-modulator (running with 10 klystrons per modulator)
- We are beginning to acquire Klystron Perveance Data
  - Analyzing archive data