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The Spallation Neutron Source Accumulator Ring RF System

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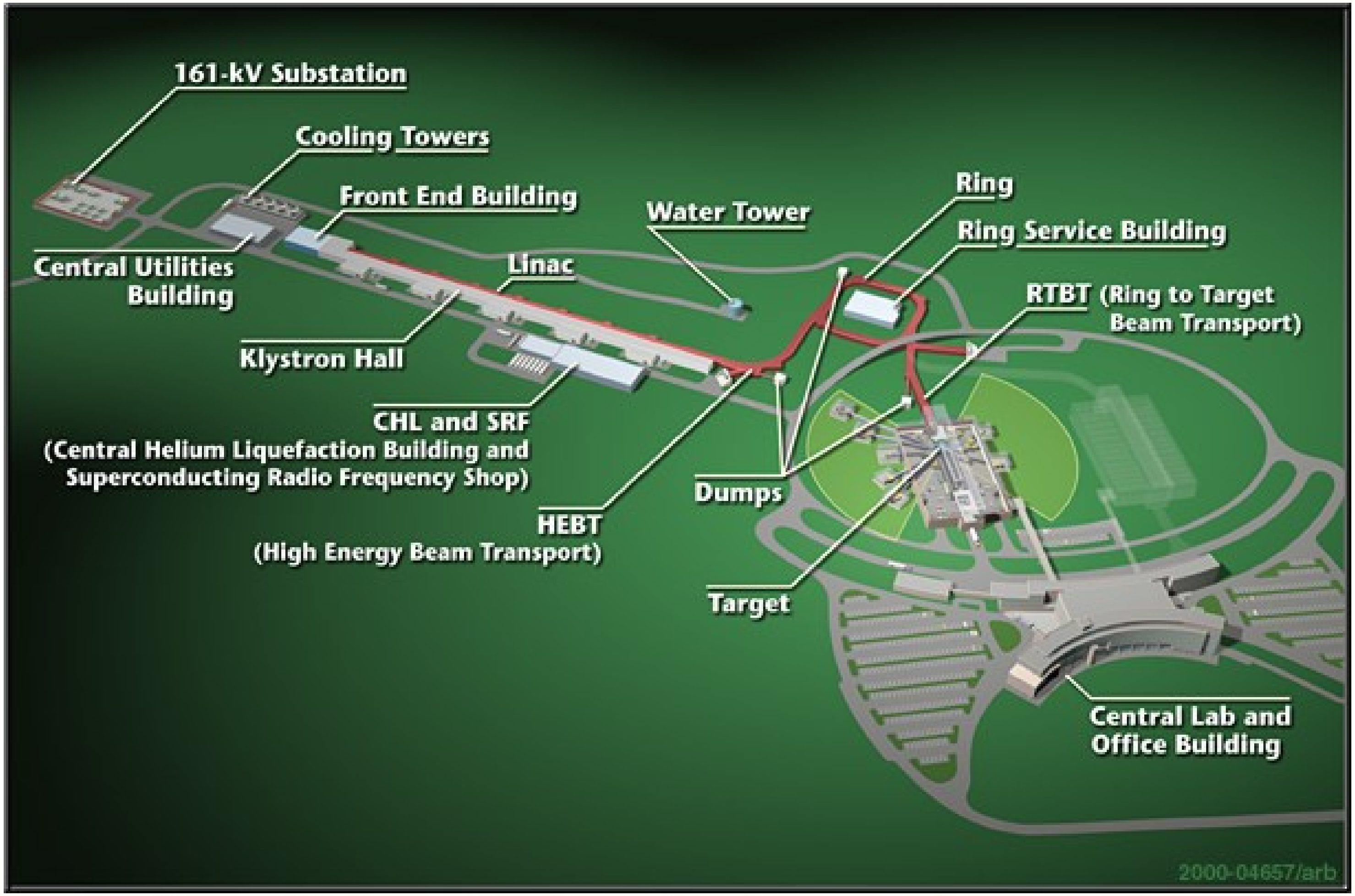
SNS SPALLATION NEUTRON SOURCE

Overview

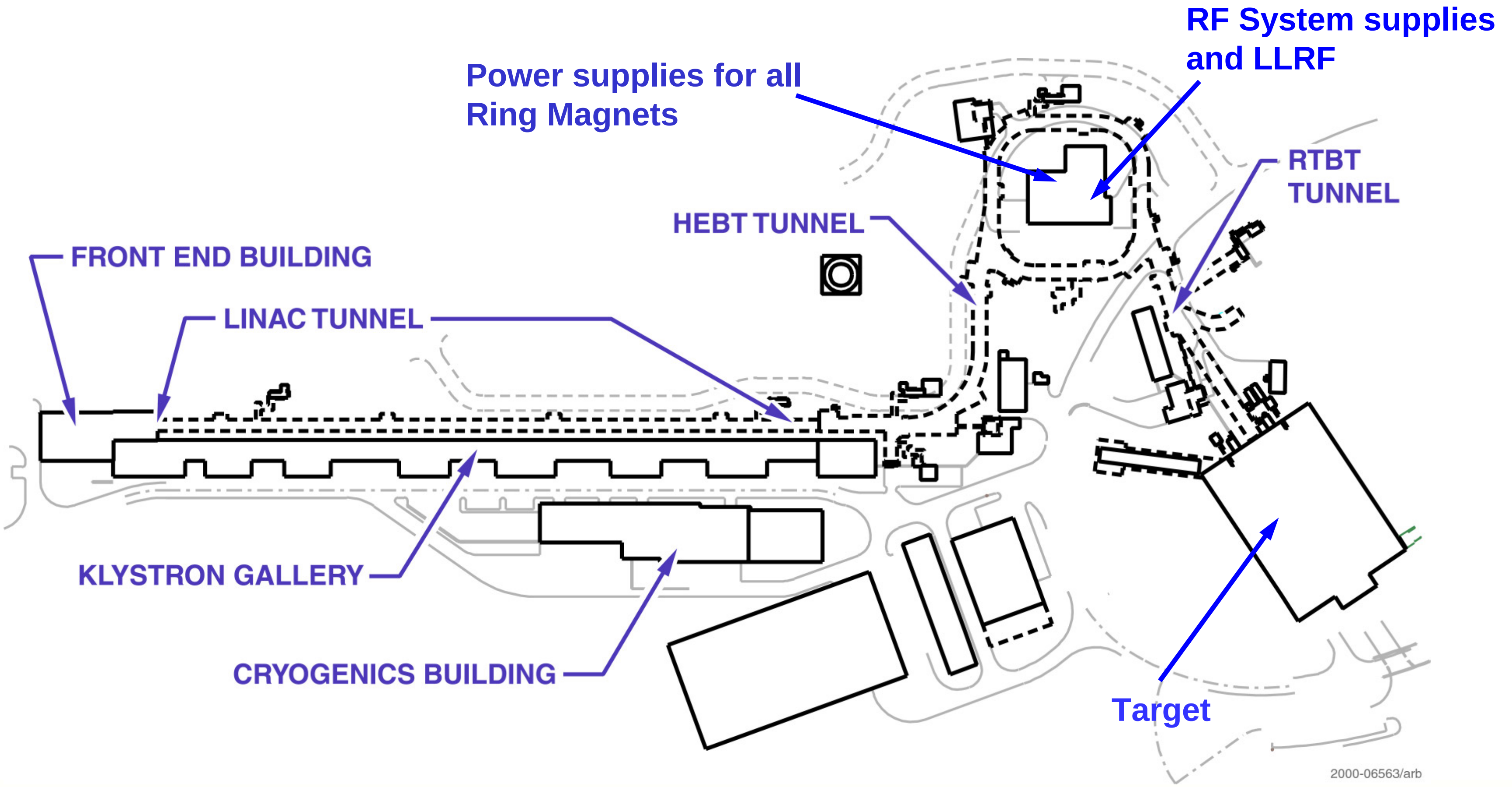
- General SNS Machine Background
- Accumulator Ring RF System Details
- Present Status
- Some current operational results
- Conclusions

SNS Facility – Artists View



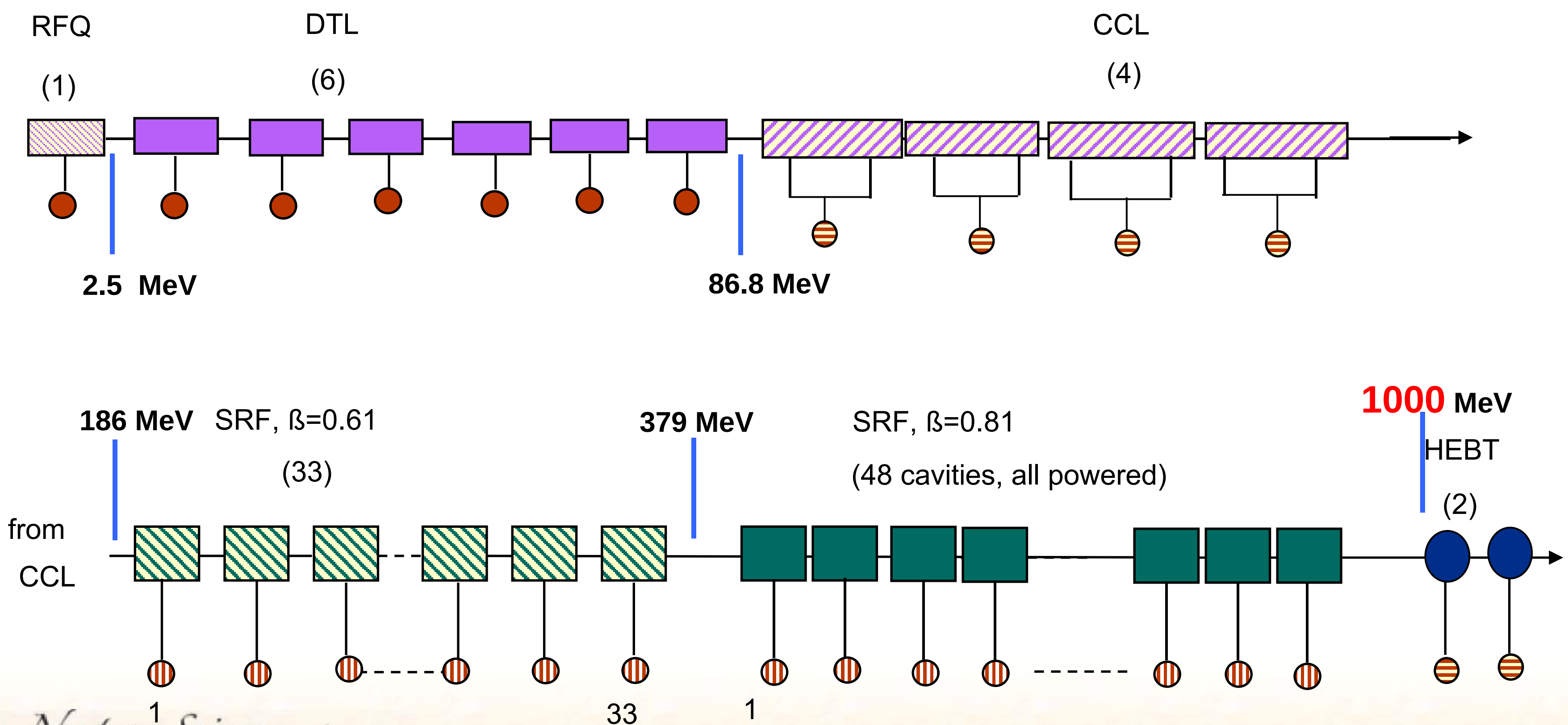
Site Photo - 2005

Overall Site Layout



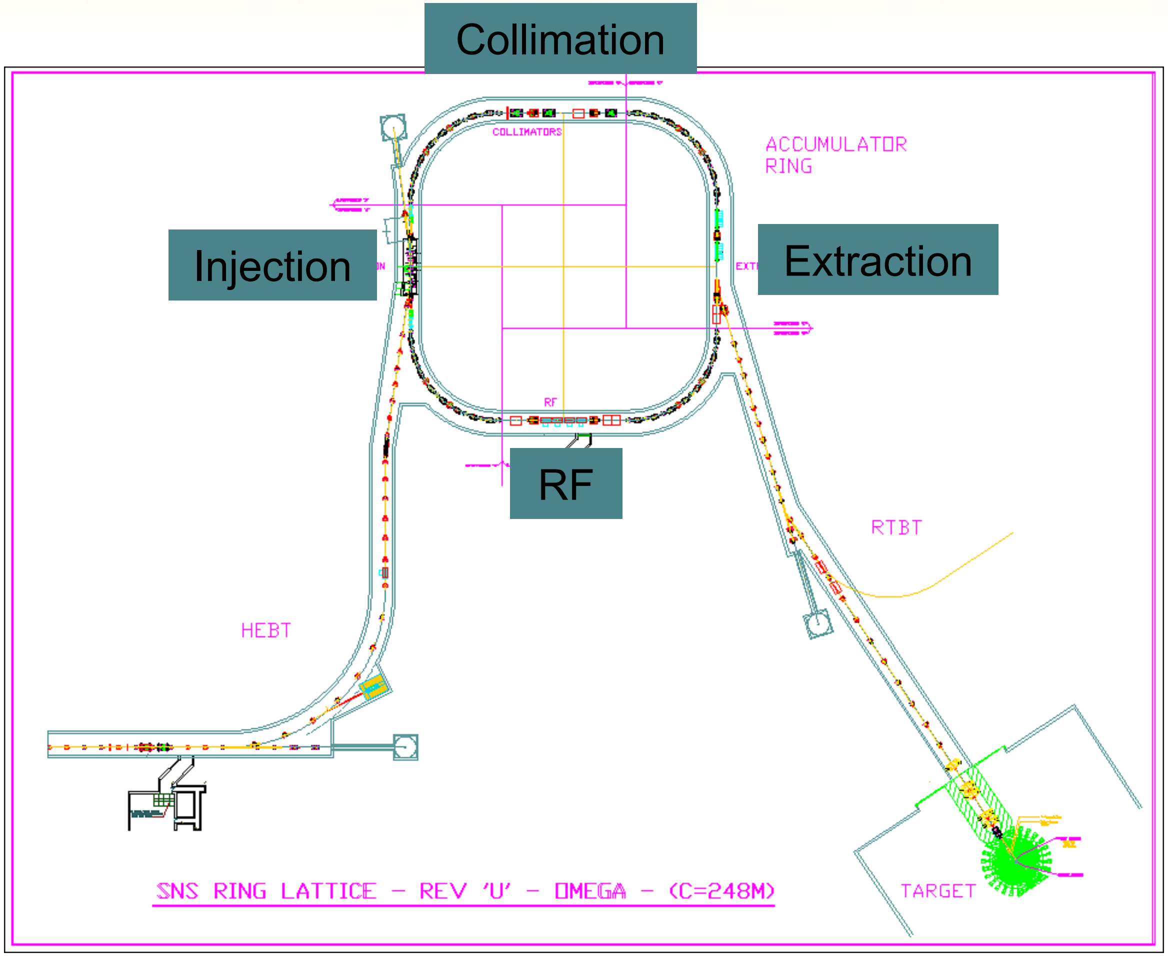
Layout of Linac RF Modules

402.5 MHz, 2.5 MW klystron	3 Transmitter	3 Modulators
805 MHz, 5 MW klystron	4 Transmitter	4 Modulators
805 MHz, 0.55 MW klystron	16 Transmitter	8 Modulators



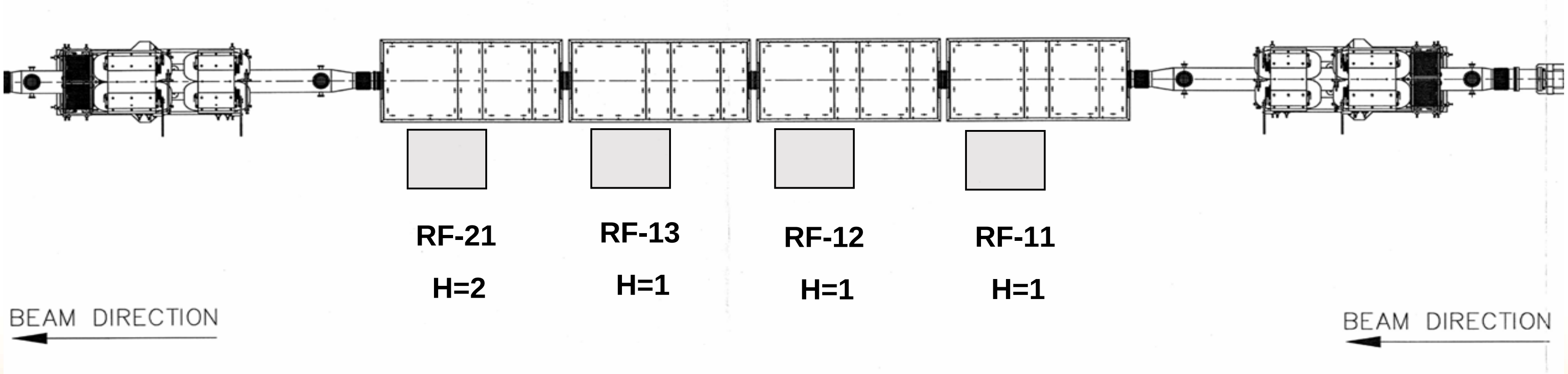
Accumulator Ring Parameters

• Circum	248 m
• Energy	1 GeV
• frev	1 MHz
• Accum turns	1060
• Final Intensity	1.5x1014
• Peak Current	52 A
• RF Volts (h=1)	40 kV
• (h=2)	20 kV
• Injected Pulse	645 ns
• Injected Gap	300 ns
• Extracted Pulse	695 ns
• Extracted Gap	250 ns



RF System Parameters

- 4 Cavities – Two Gaps per Cavity
- 3 Fundamental Revolution Frequency Cavities – 7 kV per Gap
- 1 Second Harmonic Cavity — 10 kV per Gap
- Each Cavity has one Final Amplifier
- The System must handle 52 amperes peak beam current
- Beam Loading Compensation – Cavity Tuning, Feed Forward
- Single Turn Delay RF Feedback is possible but will take some development.



Beam Loading Is A Major Issue

Here are some options we have considered.

- **I&Q Feedback**
  - Basic feedback that samples cavity field and corrects for deviations from a programmed function.
- **Cavity Dynamic Tuning**
  - Cavity bias is dynamically adjusted to compensate for the apparent cavity detuning resulting from beam current (180 Hz Sinusoidal function is used).
- **Programmed Feed Forward**
  - Provide rf drive to the amplifier chain based on predicted beam loading effects.
  - The system can learn from previous beam cycles.
- **Beam Derived Feed Forward**
  - Sample beam current and feed an inverted beam current signal into the amplifier chain.
- **One Turn Delayed RF Feedback**
  - We placed the driver amplifiers as close to the final stage as reasonably possible to allow this approach if needed.
- **Direct RF Feedback**
  - Sample the cavity voltage and feed the inverted signal directly to the final amplifier.
  - We have not planned to use this method.

Present Operational Status

- The system is installed and fully operational
- We have stored over 8e13 Protons
- The original I&Q feedback system to control Amplitude and Phase performed well at 8e13 protons.
- We have demonstrated Cavity Dynamic Tuning
- A Beam Derived Feed-Forward system included in the original design is still under development but we have completed a preliminary test demonstrating feasibility.
- Operated the 2nd harmonic cavity to help clear the beam gap.

Amplifiers and Cavities installed in Ring

RF21

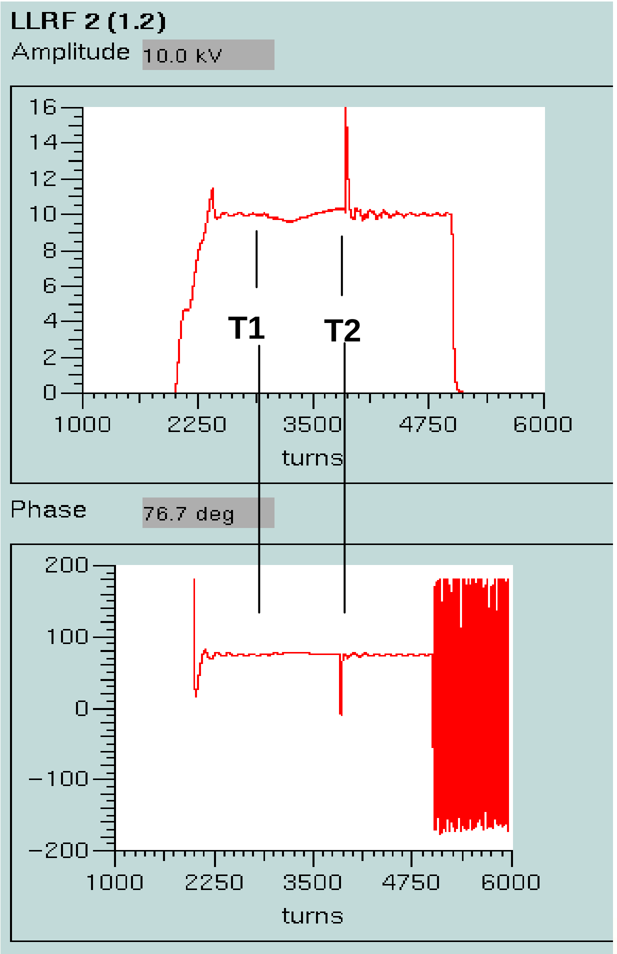
RF13

RF12

RF11

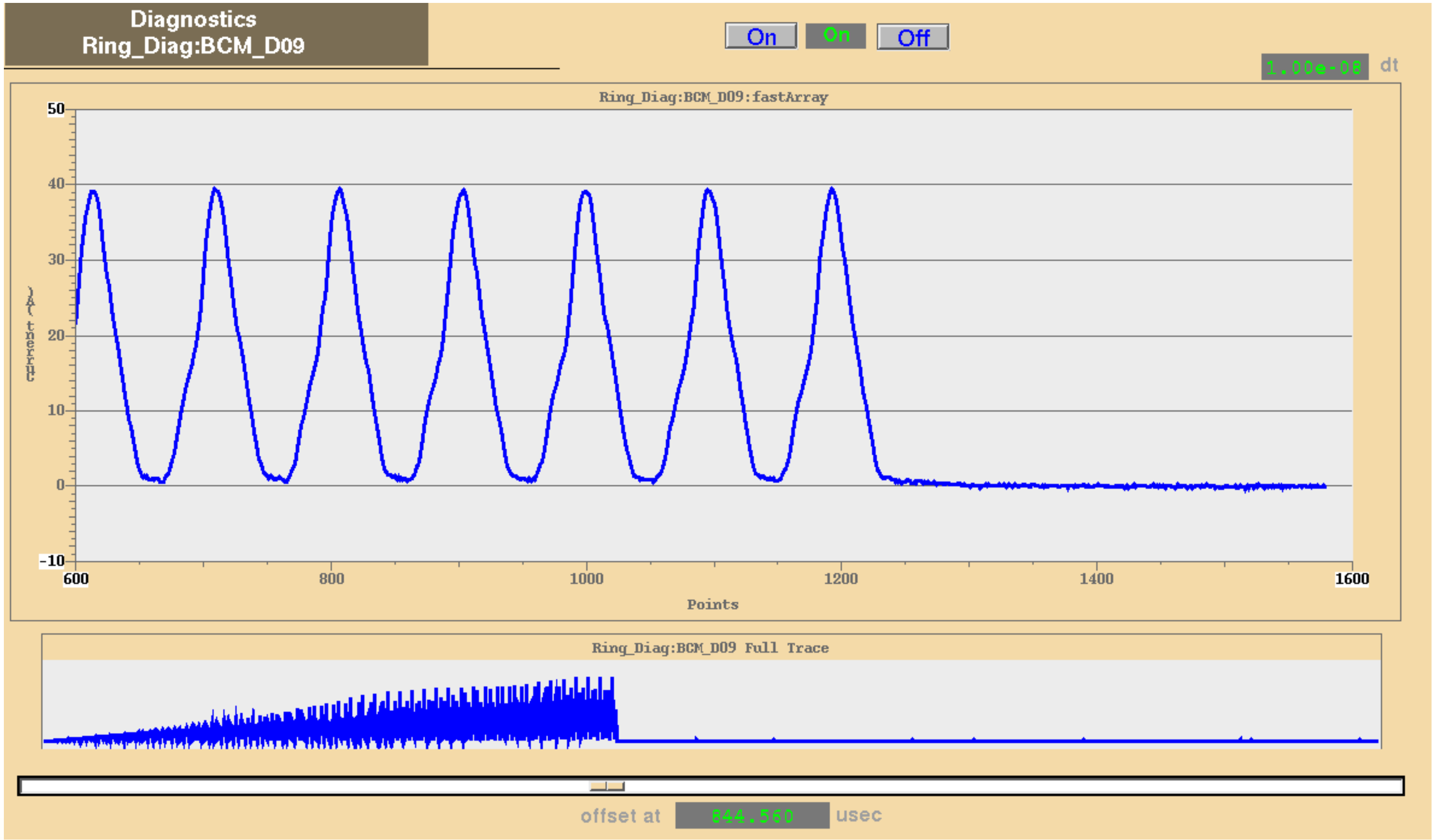
Station RF21 in Ring Service Building

RF System performance with 9e13 Protons



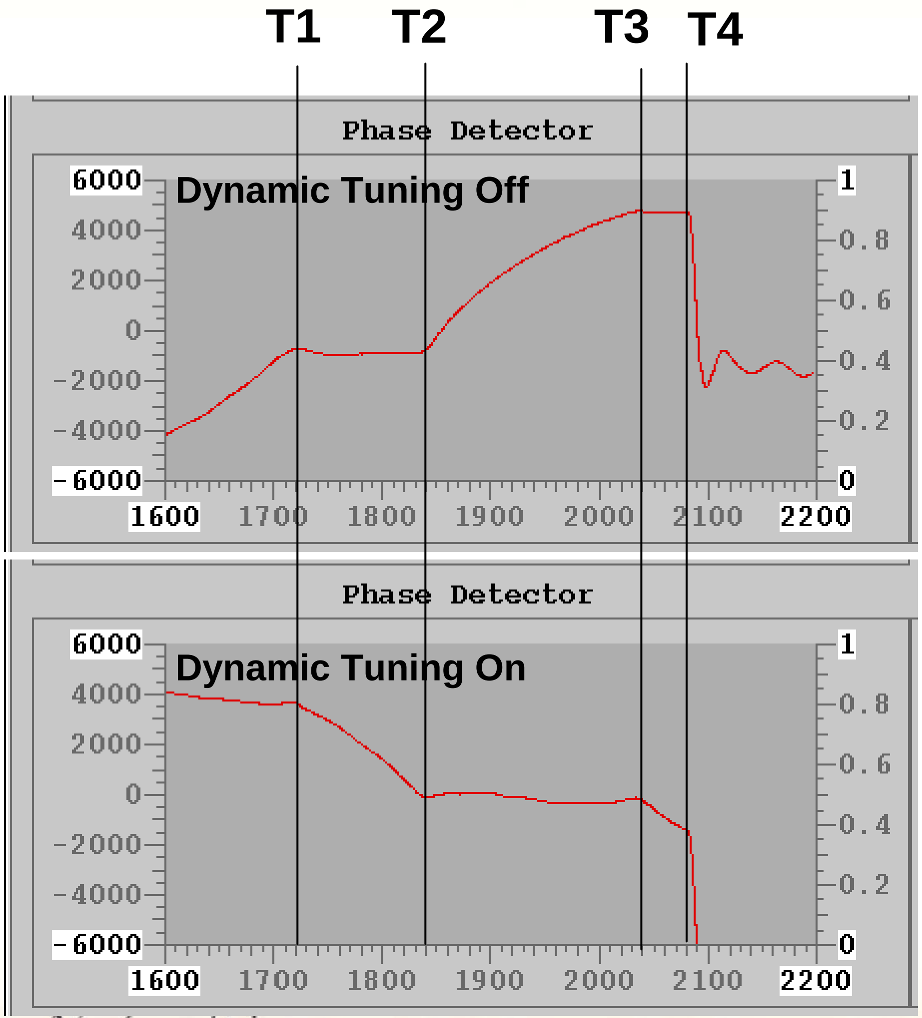
- Upper trace is cavity voltage for station RF-12
- Beam is injected at T1
- Feedback corrects for beam loading.
- Voltage excursion is about 500 volts.
- No real effort went into adjusting the feedback parameters.
- Beam is extracted at T2
- Transient at extraction can be removed by gating RF drive off at extraction
- Lower trace shows phase with respect to the beam

RF System performance with 9e13 Protons



Cavity Dynamic Tuning Example

-- Phase detector looking at the phase between Grid and Anode

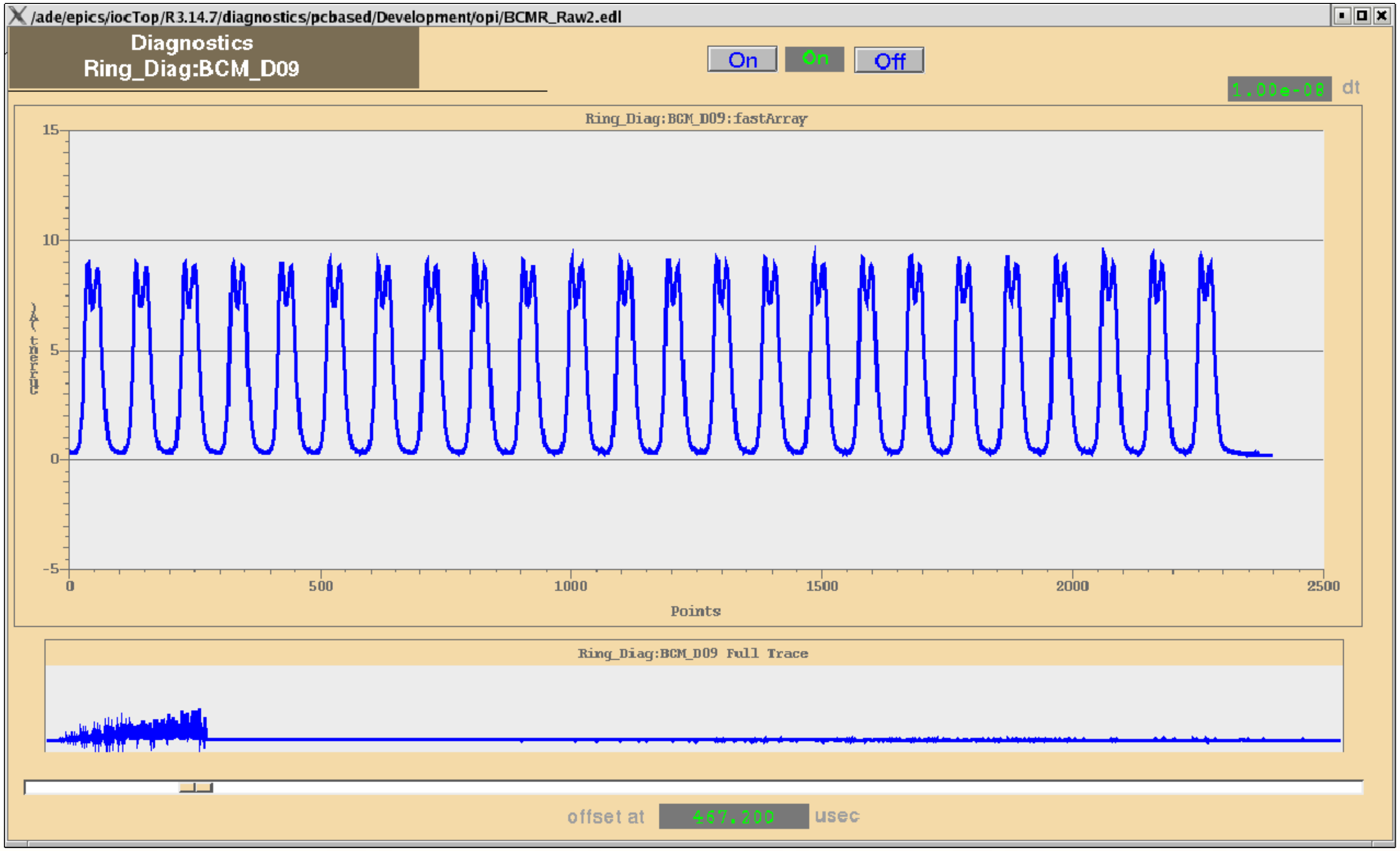


- **T1 = RF Voltage is at full programmed voltage and waiting for beam.**
  - **Lower trace shows cavity being pulled by bias function.**
- **T2 = Beam injection starts**
  - **Upper trace shows beam pulling cavity.**
- **T3 = Injection ends. Beam is stored briefly**
  - **Lower trace shows bias pulling cavity during store time.**
- **T4 = Beam is extracted**
  - **Lower trace shows cavity way off resonance with no beam loading.**

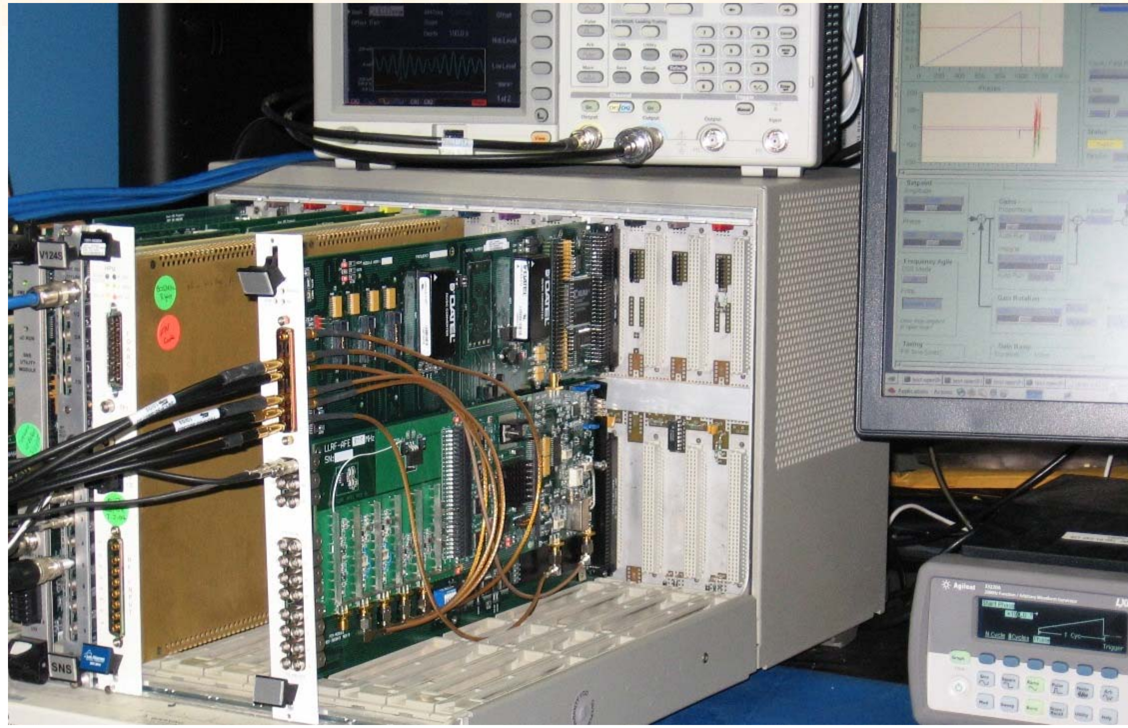
Operation with 2nd Harmonic

- The 2nd harmonic feature was intended to flatten the longitudinal beam distribution avoiding high peak currents.
- With our present intensity level we have not utilized the 2nd harmonic cavity.
- During our last run cycle we experienced problems with our Low Energy Beam Transport (LEBT) beam Chopper.
- To keep the accelerator operational we chose to limit the chopper rise time which resulted in leaking small amounts of beam into the extraction gap.
- We found that by adding more fundamental RF power and applying second harmonic component we could clear the gap sufficiently to continue operation.

Display of the beam current with 2nd Harmonic component



Ring LLRF development - Current Status – Hardware



- First prototype for testing uses 1 MHz -> 10MHz up-conversion scheme for minimizing coding work (straight I/Q scheme as in linac system)
- firmware/software modification completed.
- Preliminary Bench-test for checking control functions – done
- Site test will follow soon.
- Signal I/O:
    - Input vectors: Cavity gap V, Grid V, Beam I,
    - Output vector : RF
    - Monitors: regulation error, output power, and gap-grid phase.
    - Misc.; cavity tuning, rf gate, cycle reset, clocks etc.

Concluding Comments

- The Amplifiers can supply enough power to control beam loading well beyond the 1.5e14 Protons per Pulse.
- Existing LLRF system performs well but leaves us with some maintenance and operational concerns.
- We are pursuing a LLRF approach that will utilize much of our existing control system features and allow us to work on the system with existing tools.
- I hope to be able to show performance data at full design intensity (1.5e14 Protons Per Pulse) at PAC09.