UT-BATTELLE

Fourth CW and High Average Power RF Workshop - 2006

The Spallation Neutron Source Accumulator Ring RF System

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A. Zaltsman, K Smith (BNL)

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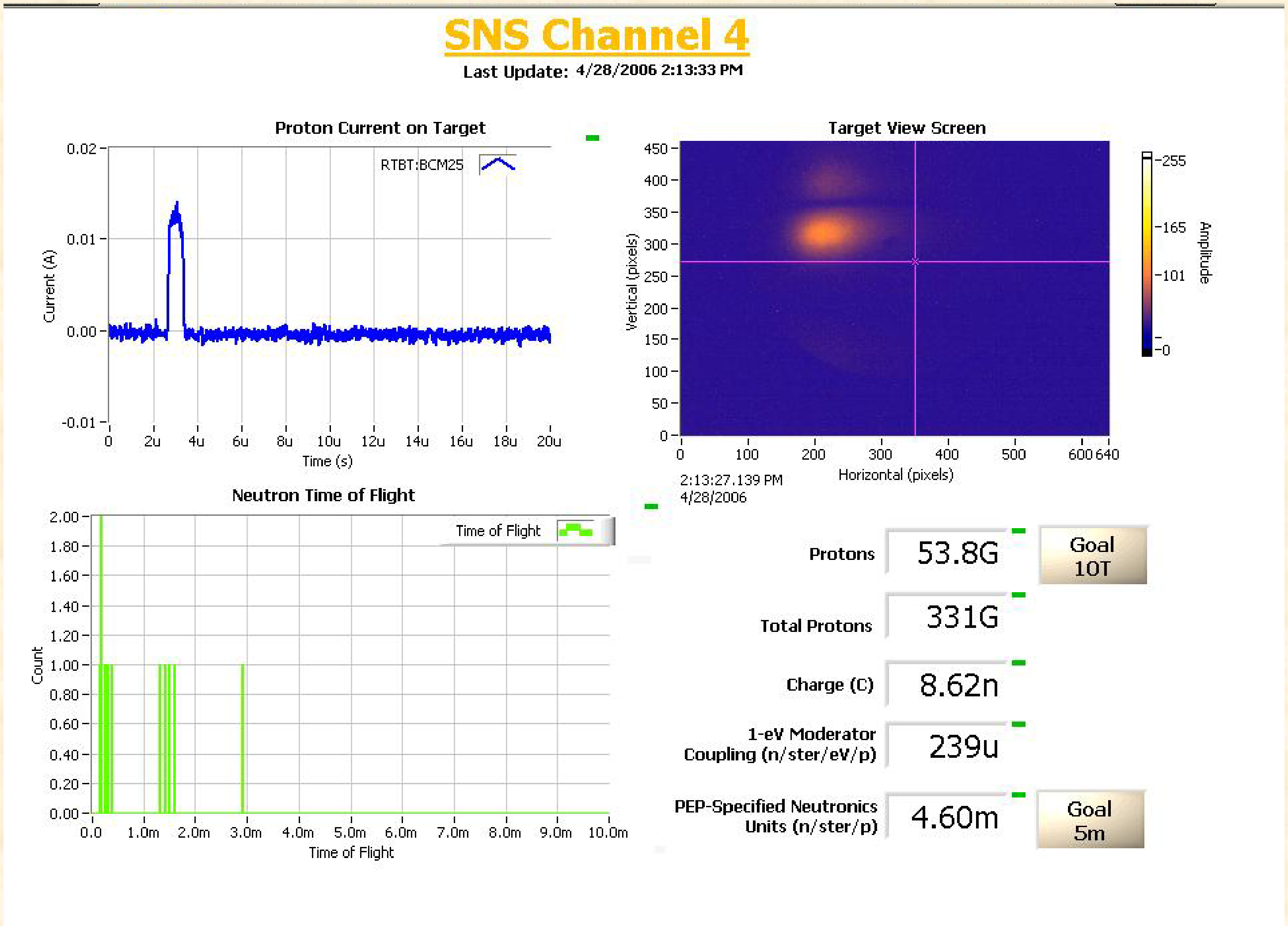
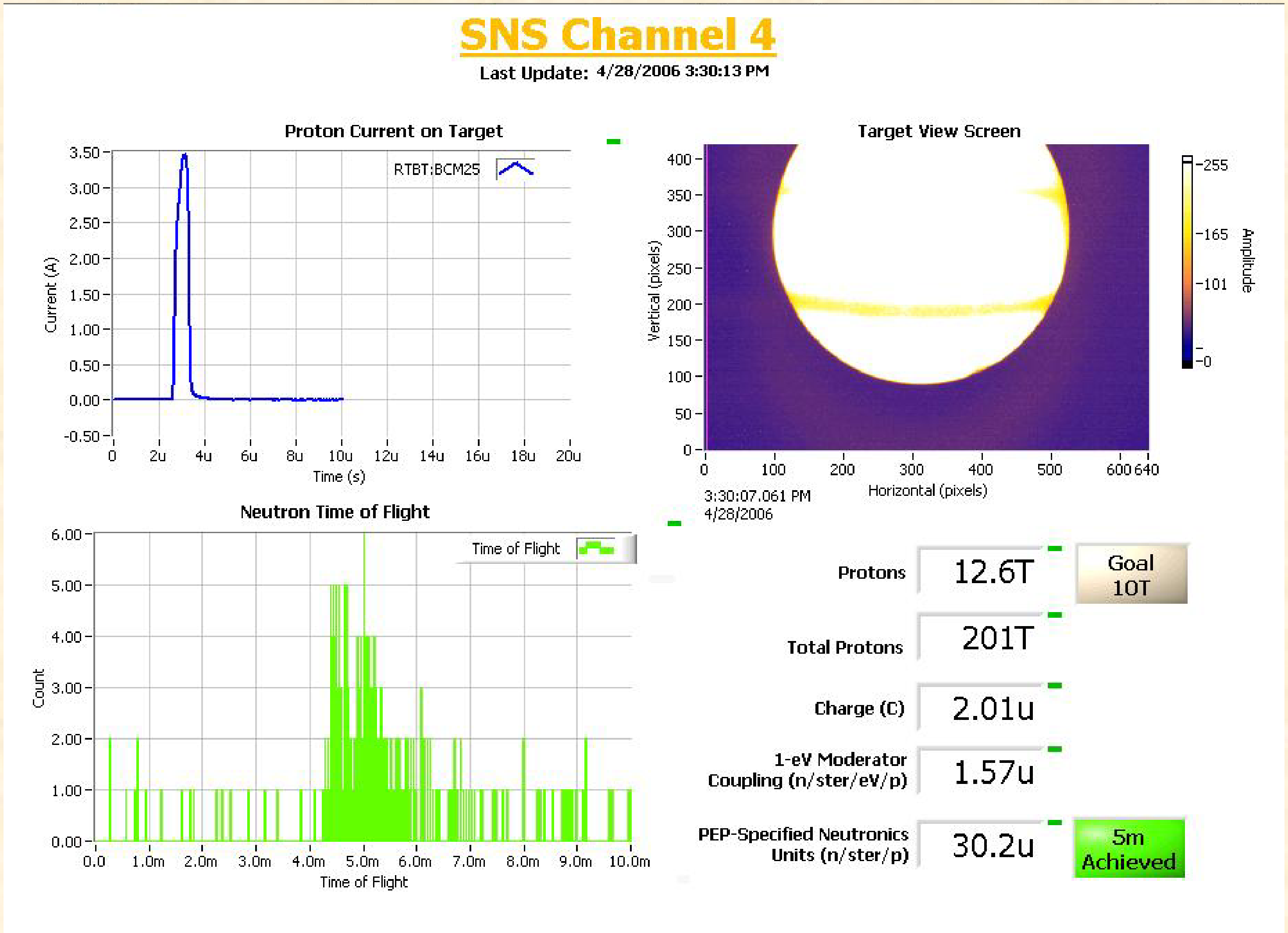
SNS SPALLATION NEUTRON SOURCE

First Beam On Target



1.2e13 Protons On Target



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SNS SPALLATION NEUTRON SOURCE

Overview

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

Brookhaven and Original ORNL Staff

BNL

Alex Zaltsman	Project Manager
Kevin Smith	LLRF Engineer
Mike Blaskiewicz	Physics
John Butler	PLC Engineer
Freddy Severino	Analog/LabView Controls
Pablo Rosas	HV Supplies

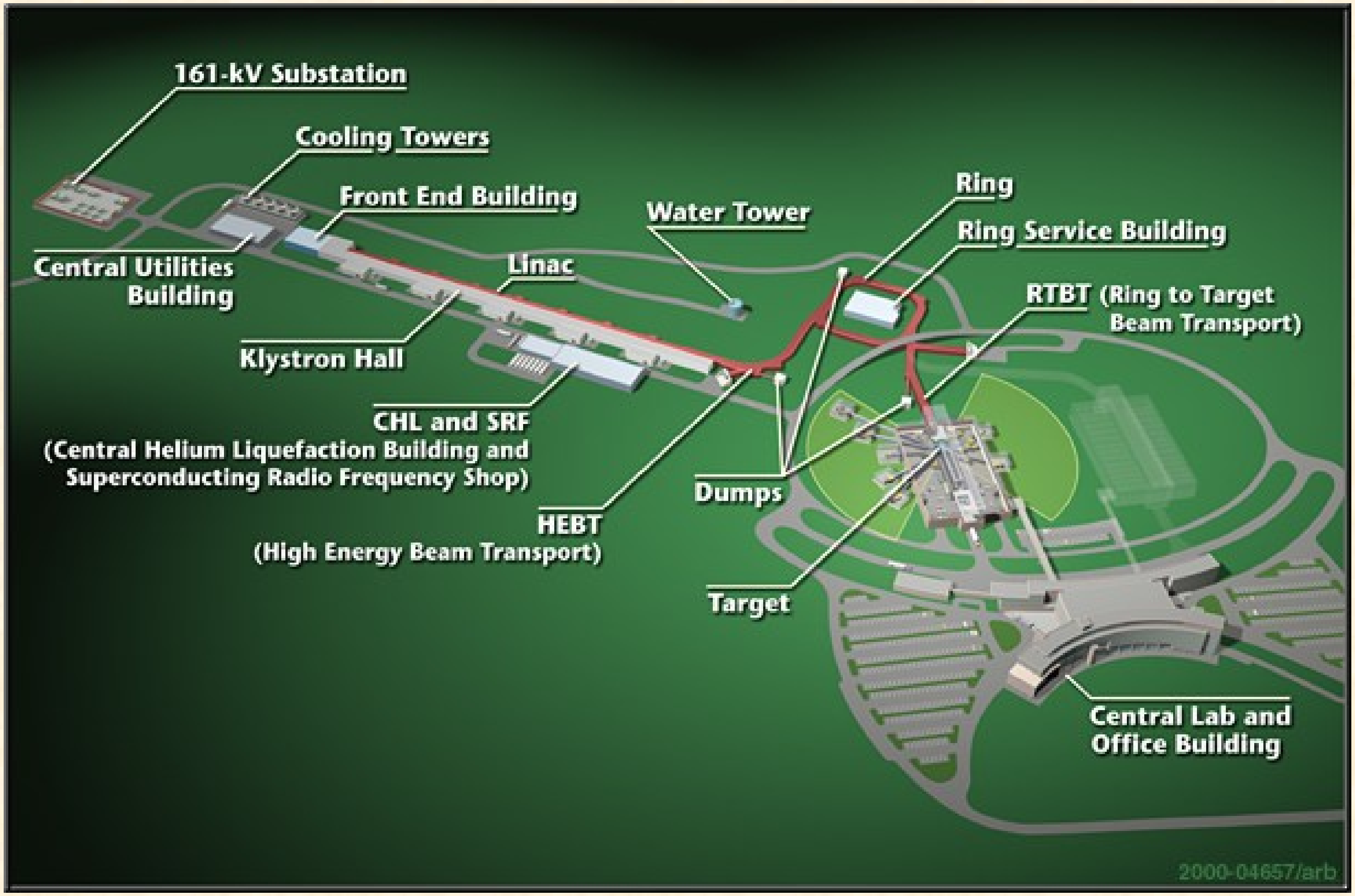
ORNL

Tom Owens	RF Engineer
Brian Gross	RF Technician
John Reed	Low Level Controls

Present ORNL Support

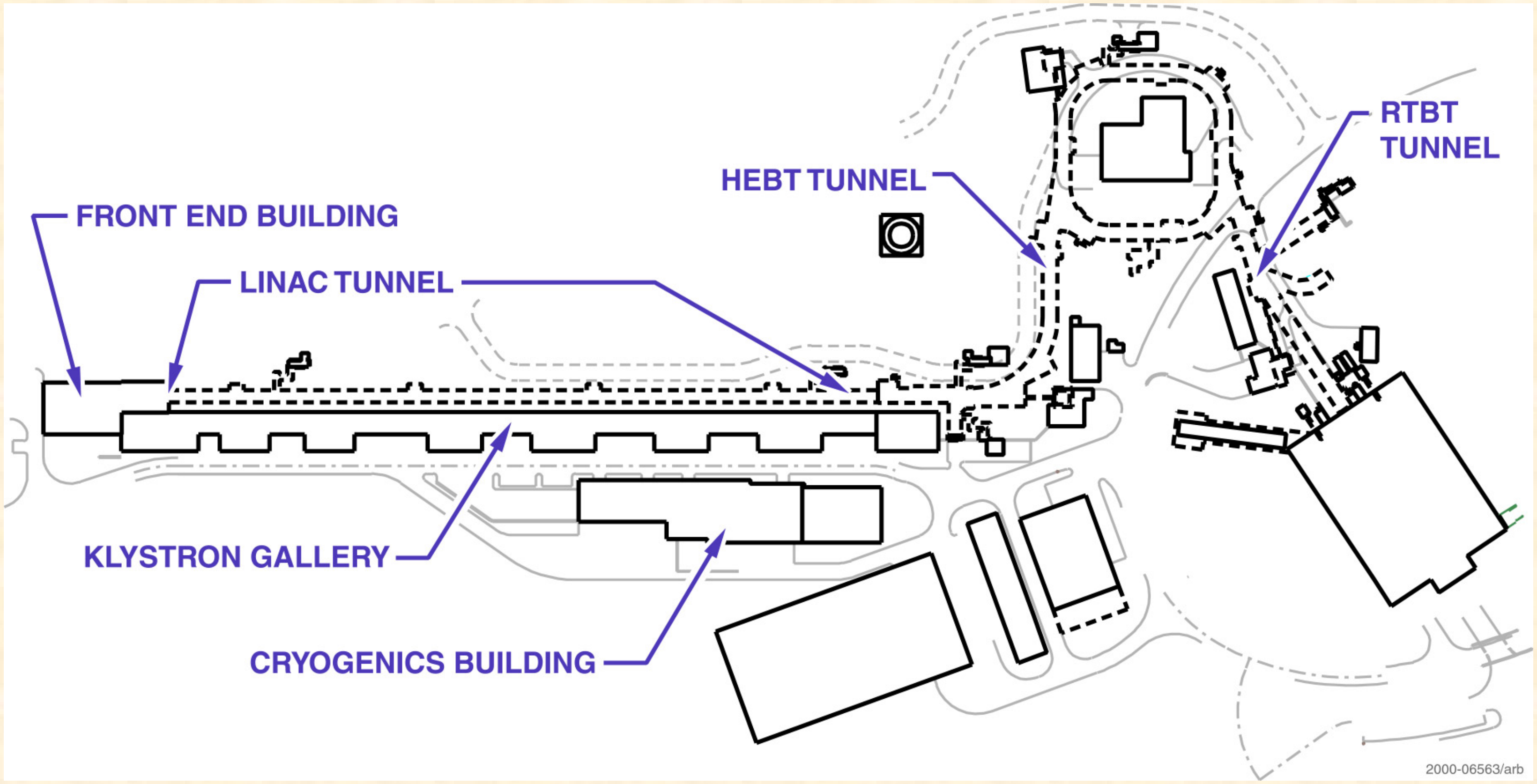
Tom Hardek	Lead RF Engineer
Maurice Piller	LLRF Engineer
Mark Crofford	LLRF Engineer
Mike Clemmer	Lead RF Technician
Dale Heidenreich	RF Technician
John De Baca	RF Technician
Mark Cardinal	RF Technician
Rob Peglow	RF Technician
Robert Wilson	RF Technician
Pam Gurd	High Level RF EPICS Controls
Kay-Uwe Kasemir	LLRF EPICS Controls
Xiaosong Geng	PLC & EPICS Controls

SNS Facility – Artists View



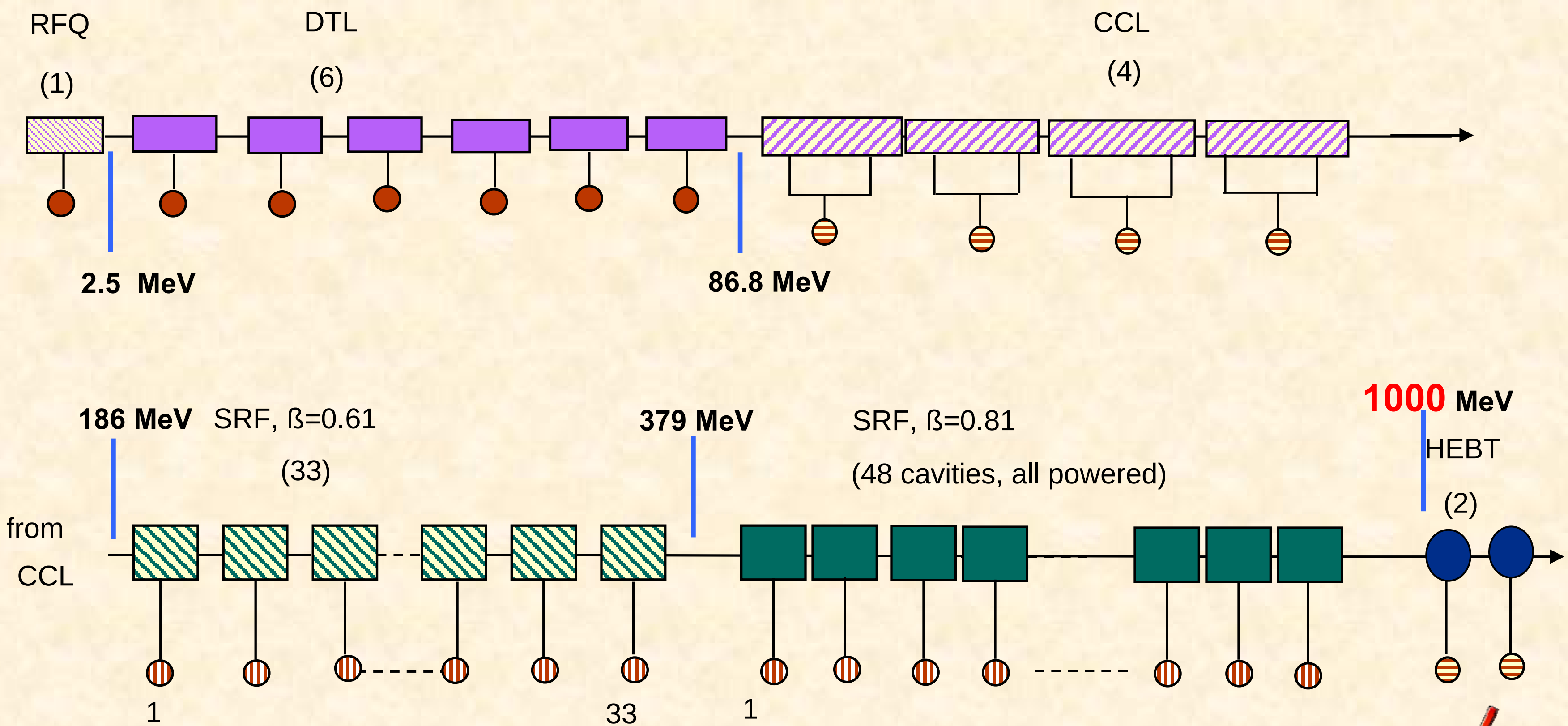
Site Photo - 2005

Overall Site Layout



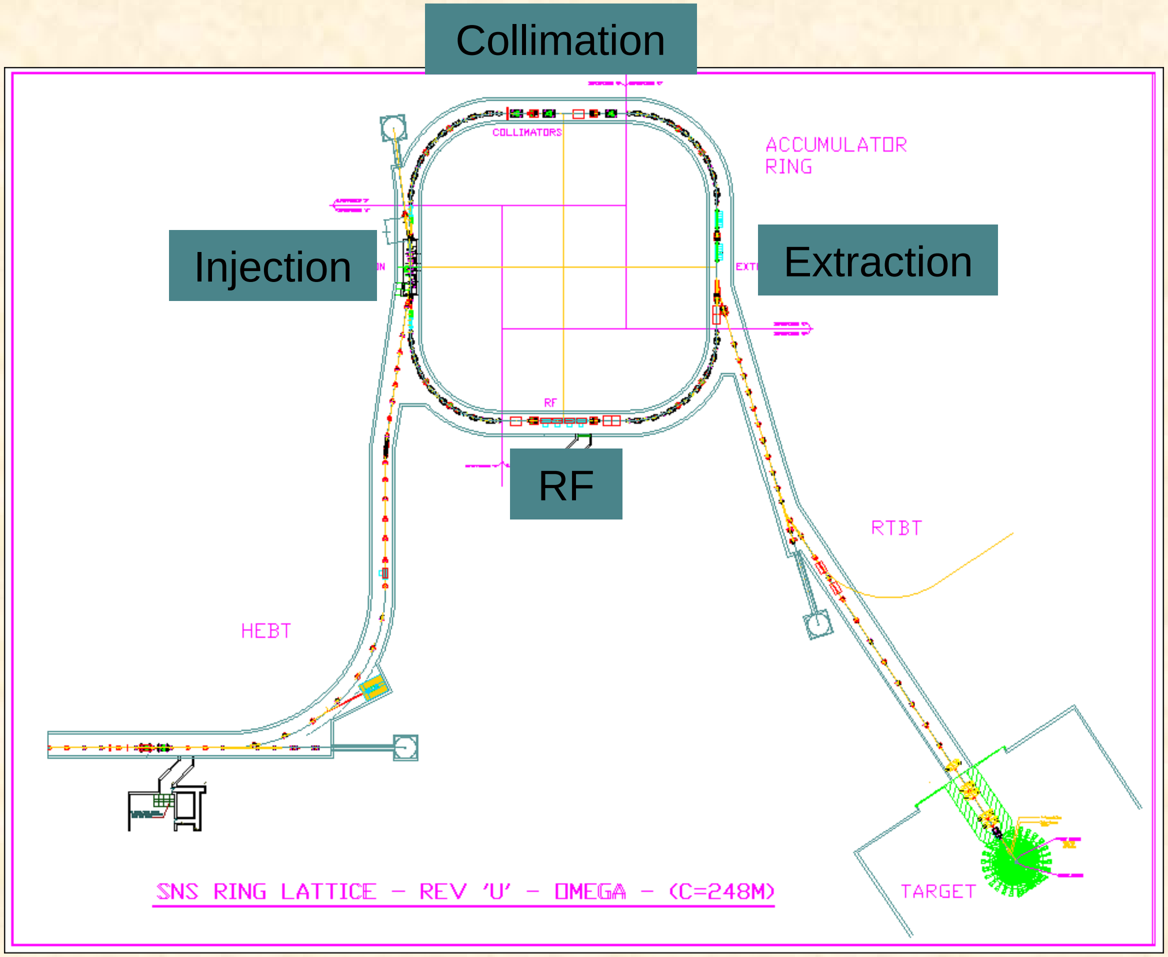
Layout of Linac RF Modules

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



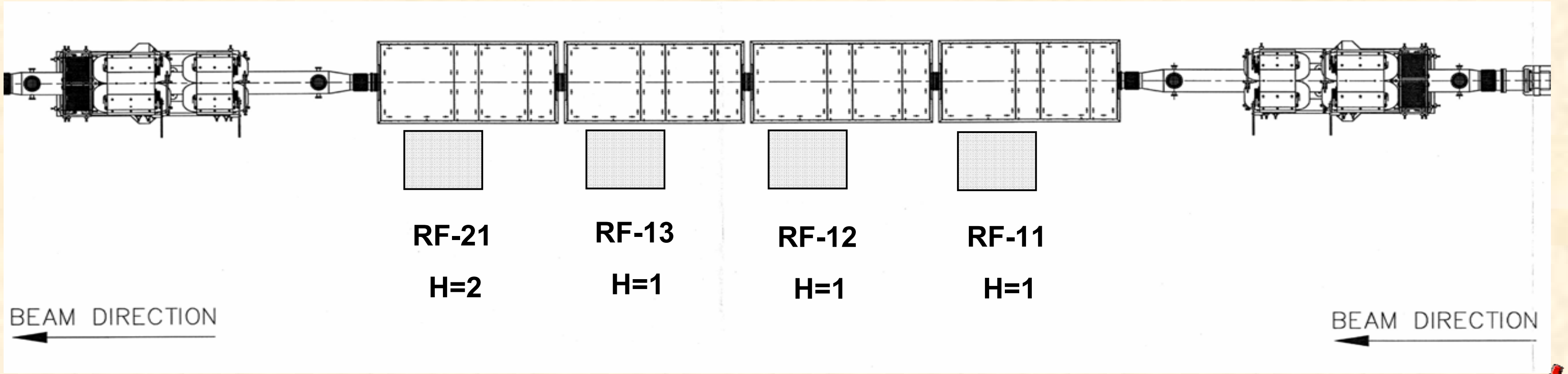
Accumulator Ring Parameters

• Circum	248 m
• Energy	1 GeV
• frev	1 MHz
• Qx, Qy	6.23, 6.20
• ξx, ξy	-7.9, -6.9
• 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.**



First RF Station at ORNL – April 2004

Final Amplifier

Cavity

Anode Power Supply Rack

Capacitor Bank

Filament Supply

Amplifiers and Cavities installed in Ring

RF21

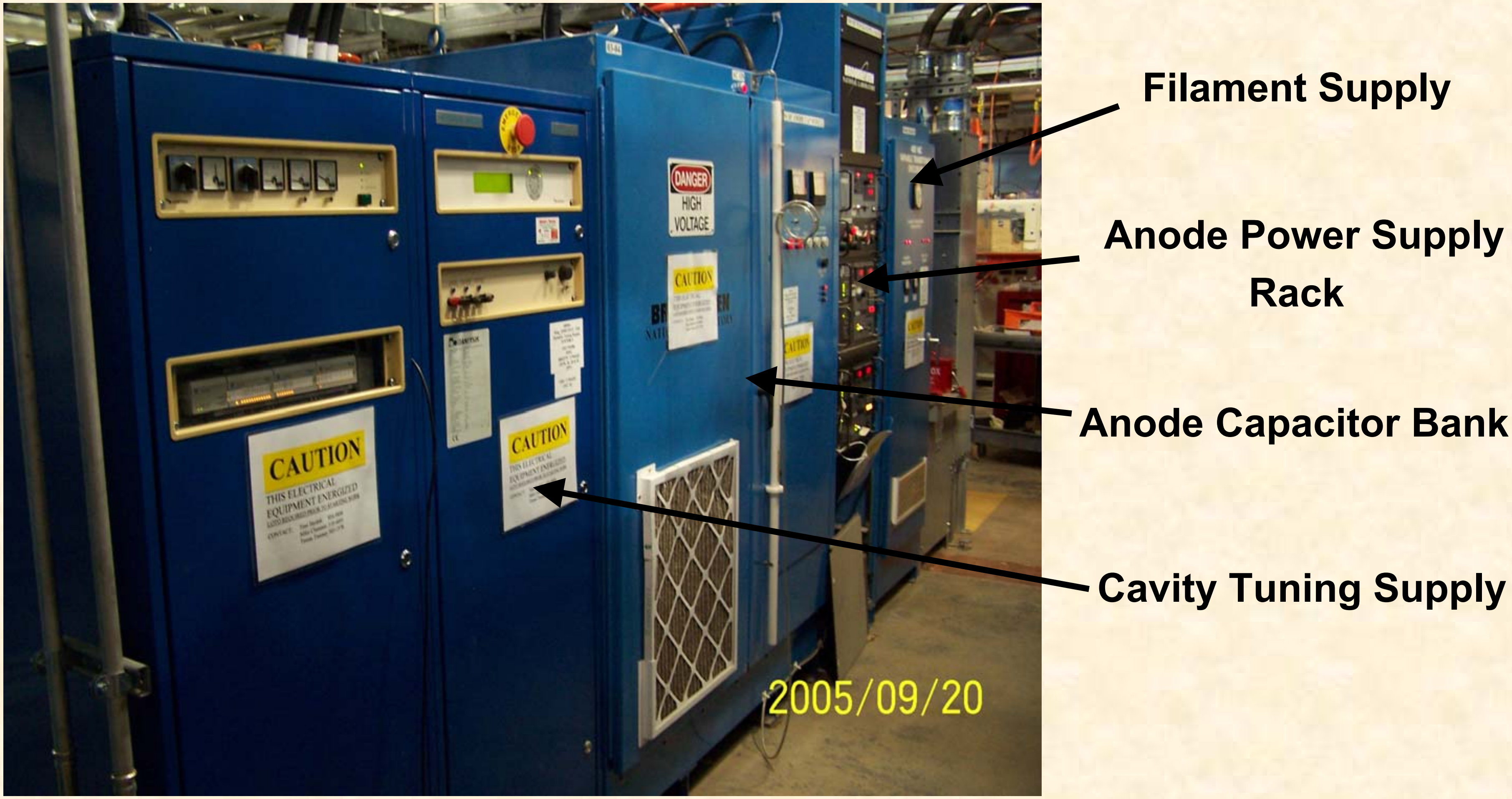
RF13

RF12

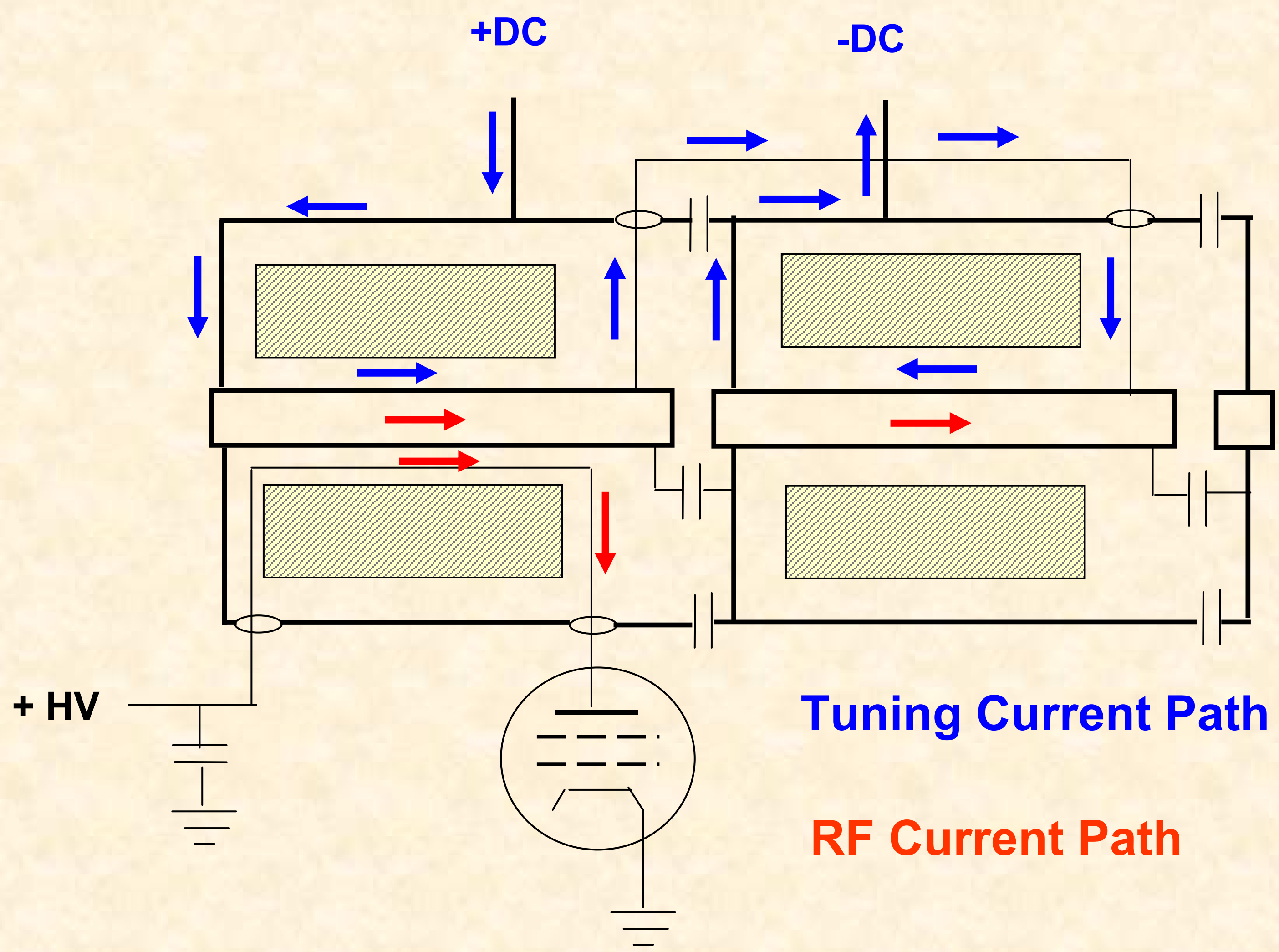
RF11

Final Amplifier – THALES TH558

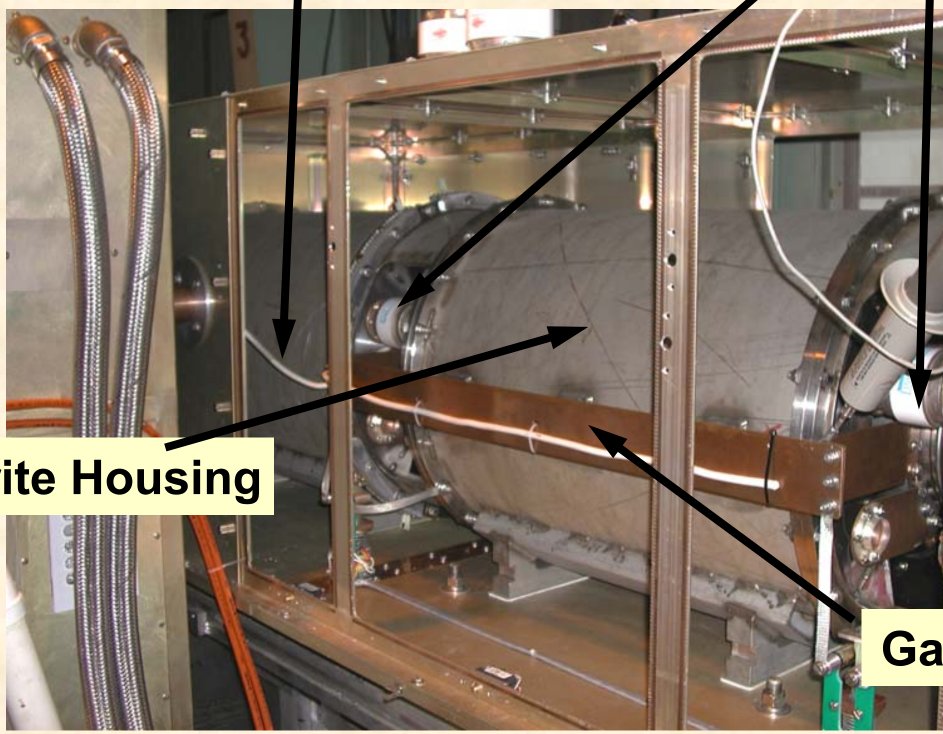
Station RF21 in Ring Service Building



DC Bias and RF Currents in the Cavity

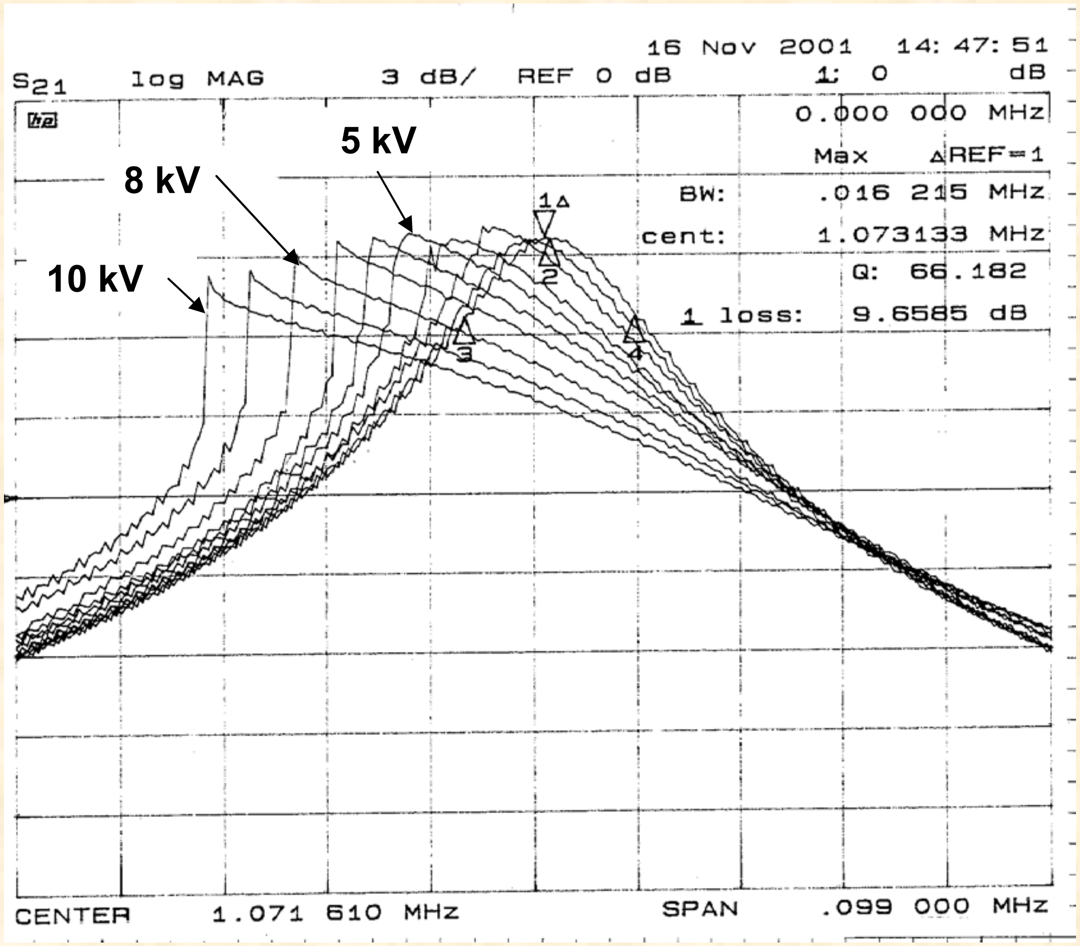


Cavity Internal View



- Drive loop is a wire that passes through a tube welded to the beam pipe.
- Gaps are connected by heavy straps.
- Ferrite housing and Beam pipe form the bias winding

Cavity Resonance Curves



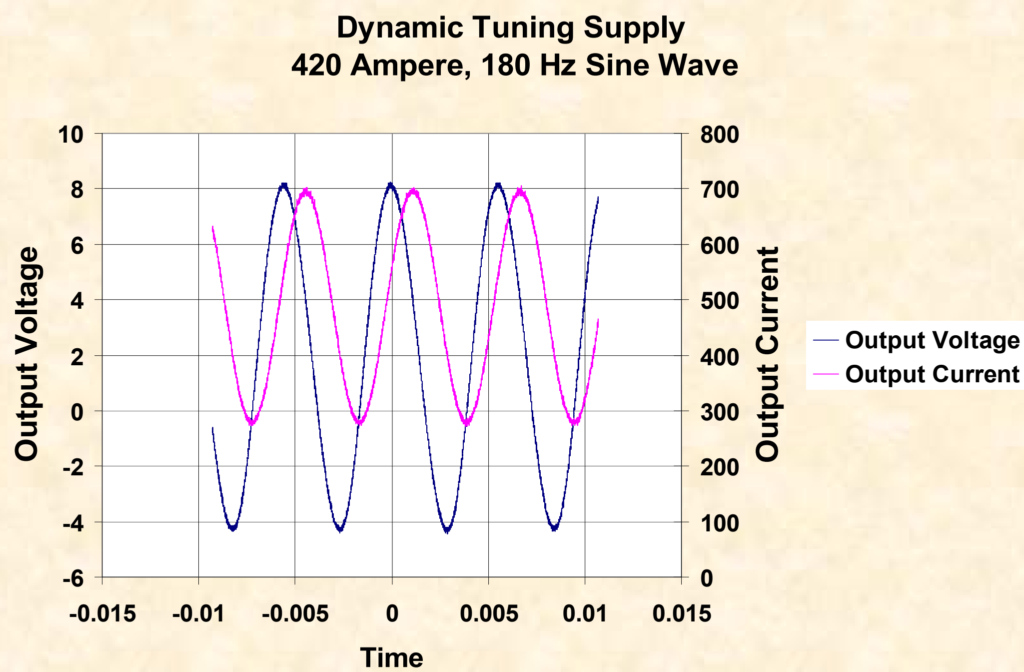
- Note that the higher voltage resonance curves are really skewed

- We are probably pushing the ferrite too hard.

- Amplitude feedback loop will be difficult.

Dynamic Tuning Supply

- System design requires a 450 ampere 180 Hz sinusoidal current swing from the Cavity Dynamic Tuning Supply to help compensate for beam loading.
- Excessive connecting lead inductance could require higher voltages than available from the supply.
- We measure 25.5 uHy. - Well within the supply range.
- Supply capable of -18 Volts to +24 Volts.



Ring RF Control Room

High Level RF Control Racks

LLRF Analog Modules

LLRF VME Boards

Present Operational Status

- **The system is fully operational**
- **We have stored 5e13 Protons**
- **The Slow Feedback system had trouble holding 5e13 protons but we have not spent much time adjusting the system (*one 4 hour shift*)**
- **We have not tried Cavity Dynamic Tuning**
- **The Feed-Forward system included in the original design is under development**

Ideal RF Waveform and Calculated Bunch Shape

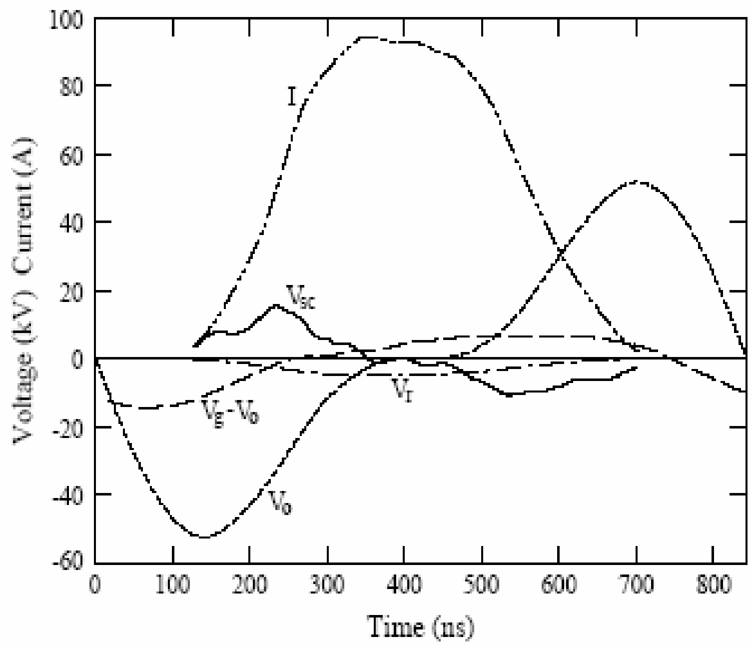


Fig. 5.8.1: Simulation results for SNS just before extraction including beam loading for h = 1 with one turn delay feedback. Parameters are described in the text and Table 5.8-2.

V_0 = Ideal RF Voltage

$V_g - V_0$ = Actual RF Voltage - Ideal RF Voltage

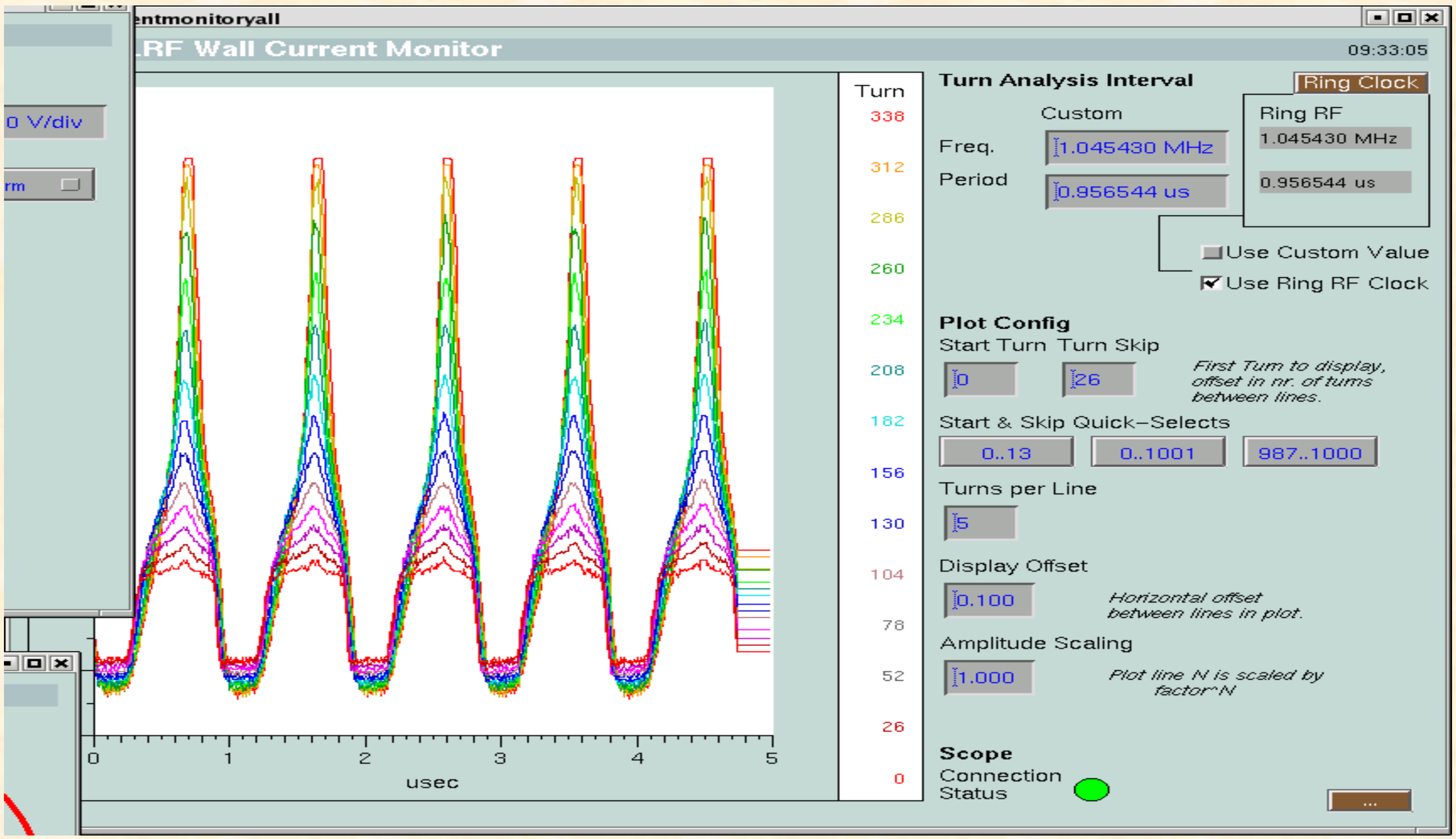
V_{sc} = Space Charge Induced Voltage

V_r = Voltage Due To Parasitic Resistance

I = Beam Current

- 2nd harmonic is added to reduce the peak beam current.
- For low intensity beam cycles the 2nd harmonic cavity is not needed.

4e13 Protons – Nicely Bunched, No 2nd Harmonic



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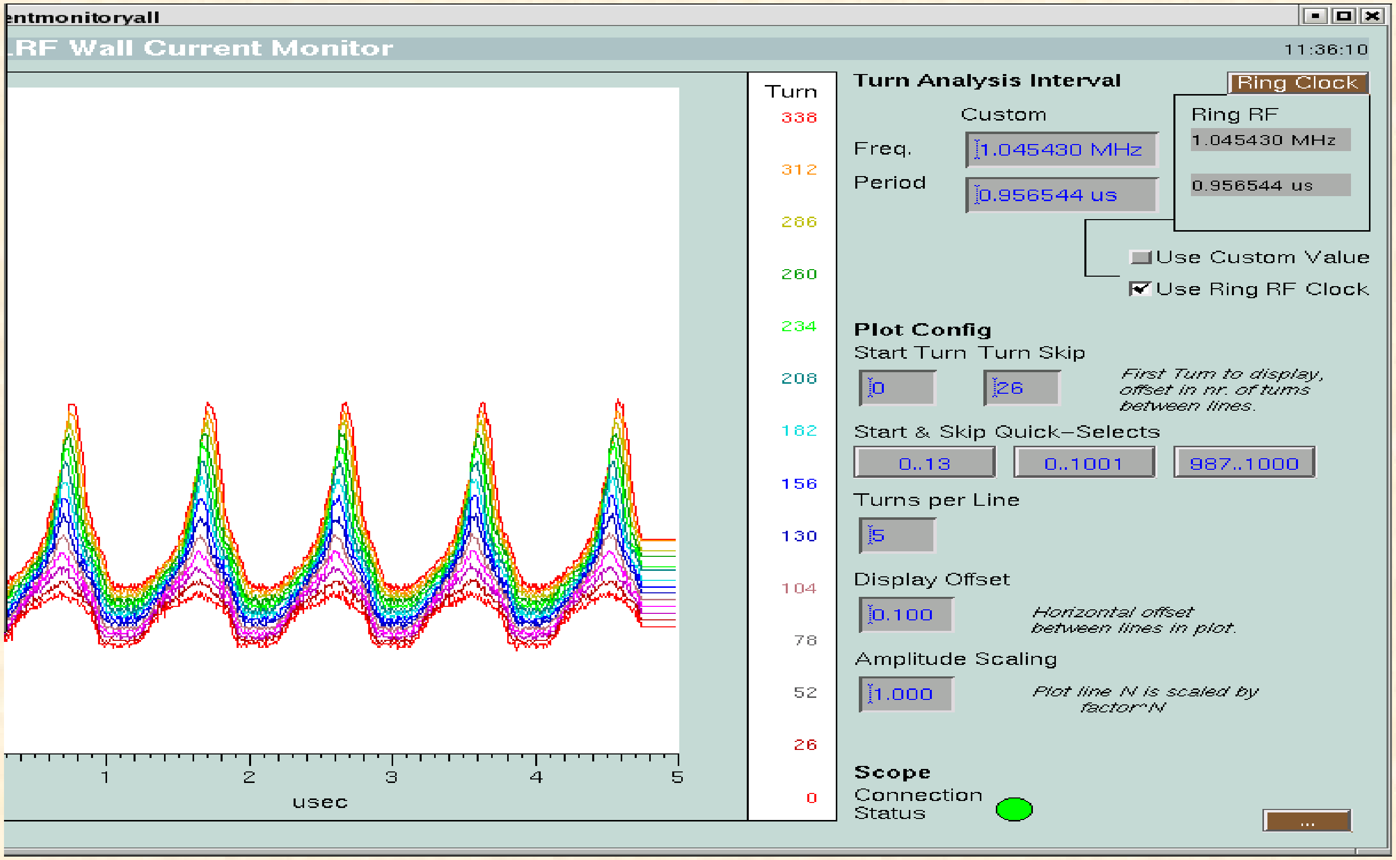
5e13 Protons – Present RF Limit



Low Level System Screen

Conclusions

- **Final Amplifiers are capable of supplying the current needed to compensate for beam loading**
- **Cavity Dynamic Tuning will be necessary**
- **With some adjustment the slow analog feedback along with Cavity Dynamic Tuning should allow us to reach design intensity.**
- **A Feed-Forward system that records a beam current sample and feeds it to the amplifier to counter beam current will be necessary for higher intensities.**