Status of the Third RF Cavity Upgrade for the IPNS RCS

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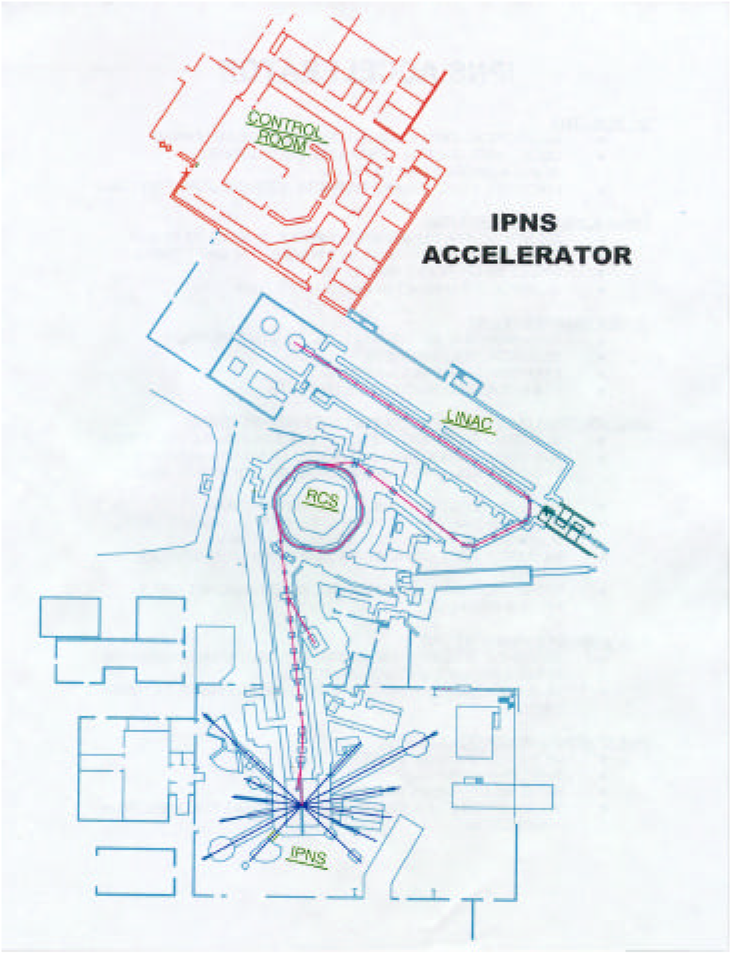
RCS Third Cavity Upgrade—Rationale

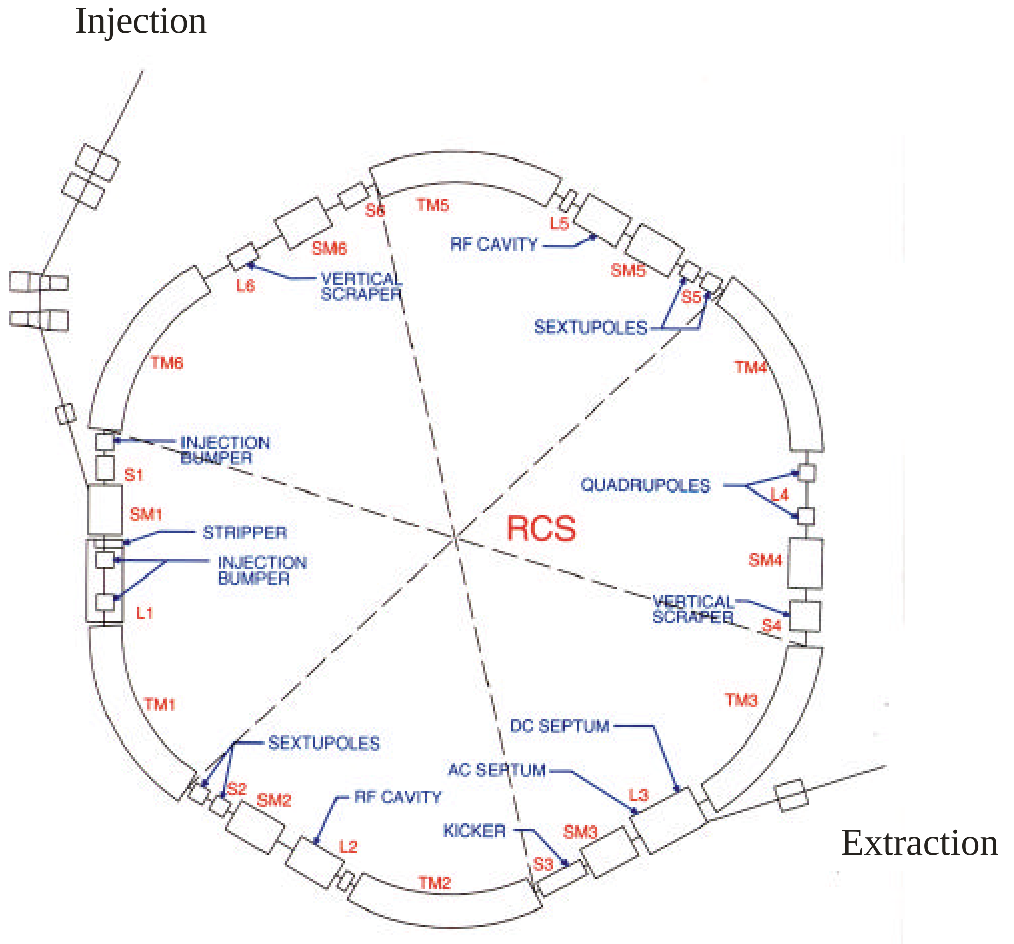
- Provide a backup rf cavity—improve reliability.
- Increase current limit—more neutrons
  - More and/or faster experiments
  - Better resolution

Rapid Cycling Synchrotron

- Circumference=42.9 m
- Two cavities
- 21 kV, rf accel. voltage
- 3rd cavity planned in L6
- 30 Hz
- Began operation in 1981

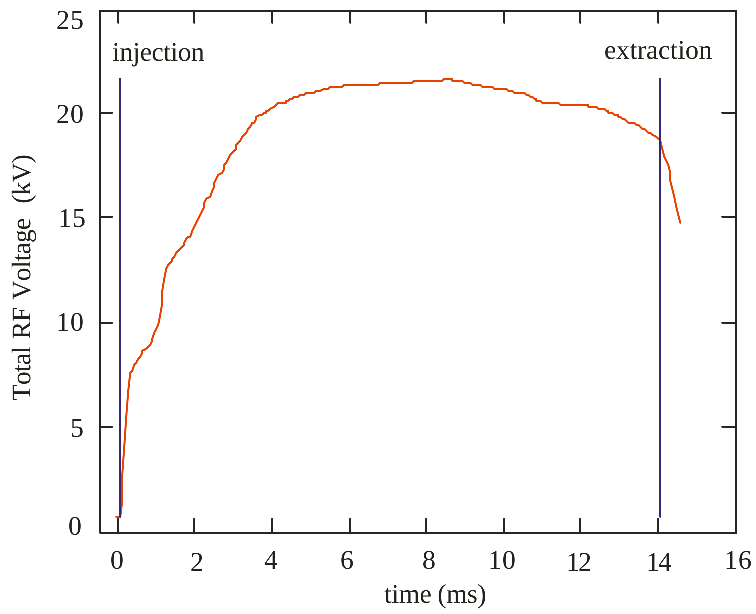


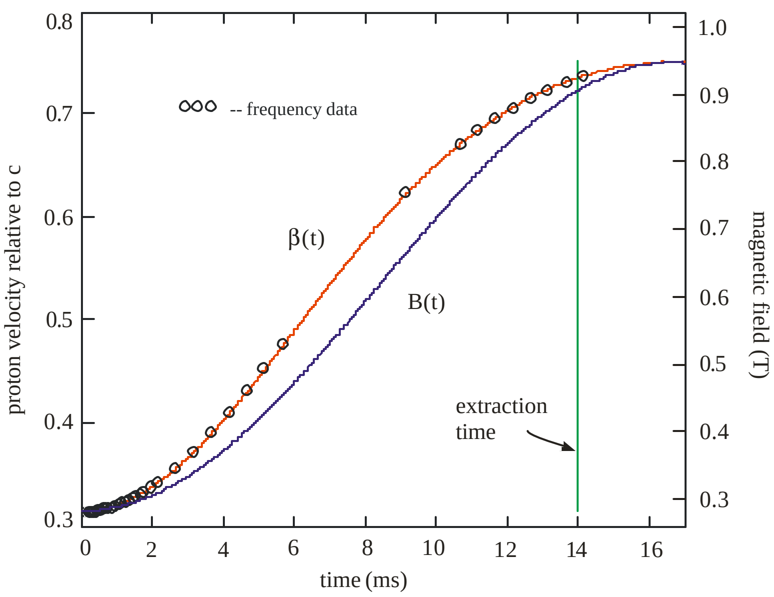
IPNS RCS



Injection
TM5
S6
L5
RF CAVITY
SM6
SM5
L6
VERTICAL
SCRAPER
S5
SEXTUPOLES
TM6
TM4
INJECTION
BUMPER
S1
QUADRUPOLES
L4
SM1
STRIPPER
RCS
INJECTION
BUMPER
SM4
VERTICAL
SCRAPER
S4
L1
TM1
TM3
DC SEPTUM
SEXTUPOLES
AC SEPTUM
L3
S2
SM2
RF CAVITY
KICKER
SM3
L2
S3
TM2
Extraction

Physical Description
RCS Voltage and Magnetic Field Programs

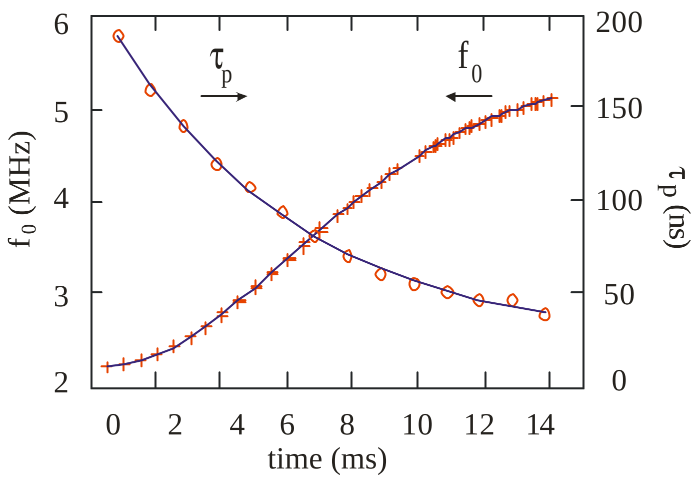


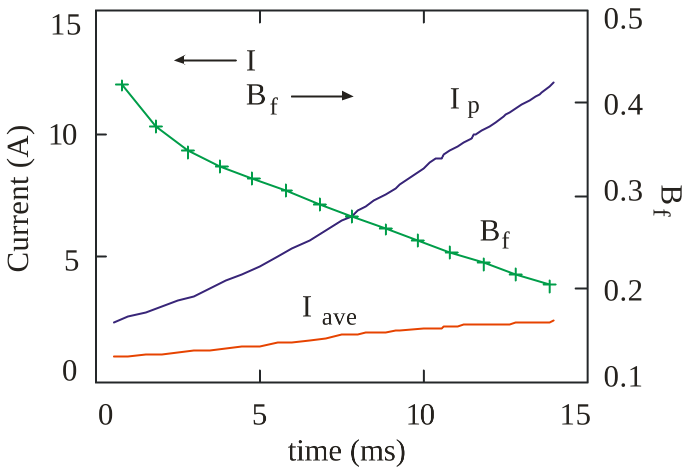


Physical Description, con't

- 50 MeV, injection
- 3.7×10^{12} protons injected
- 450 MeV, 3.2×10^{12} protons extracted
- Combined function magnets
- Pulsed quads
- Sextupoles
- Tunes:
  - 2.20 horizontal
  - 2.35 vertical

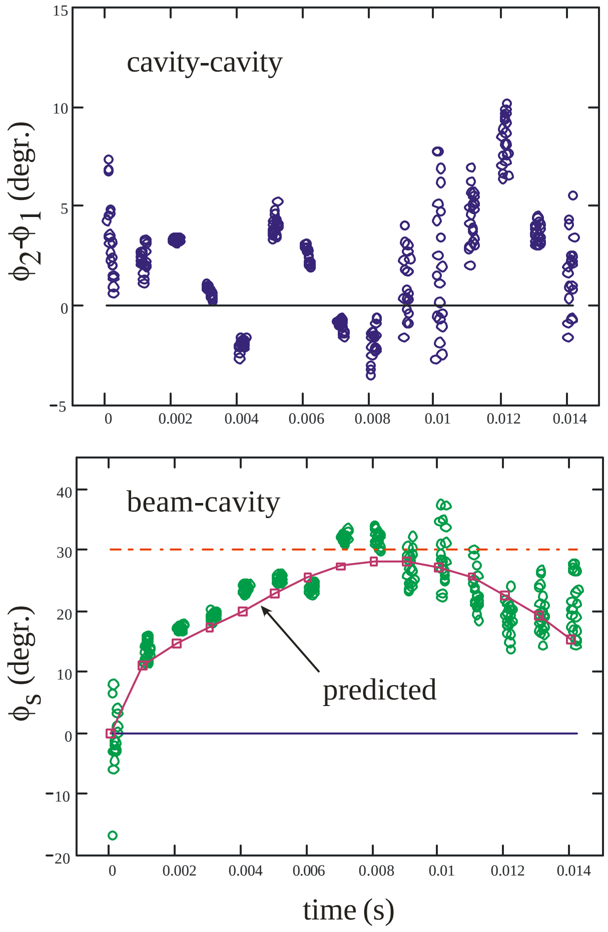
RCS bunch frequency, pulsewidth, B_f, and current

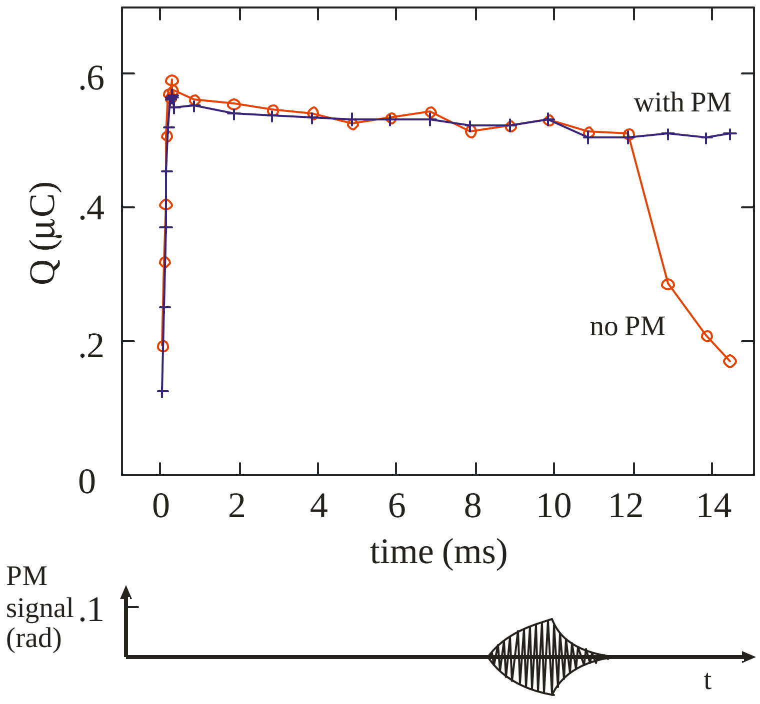




Physical description, con’t

Cavity-cavity phase modulation (PM) adds stability

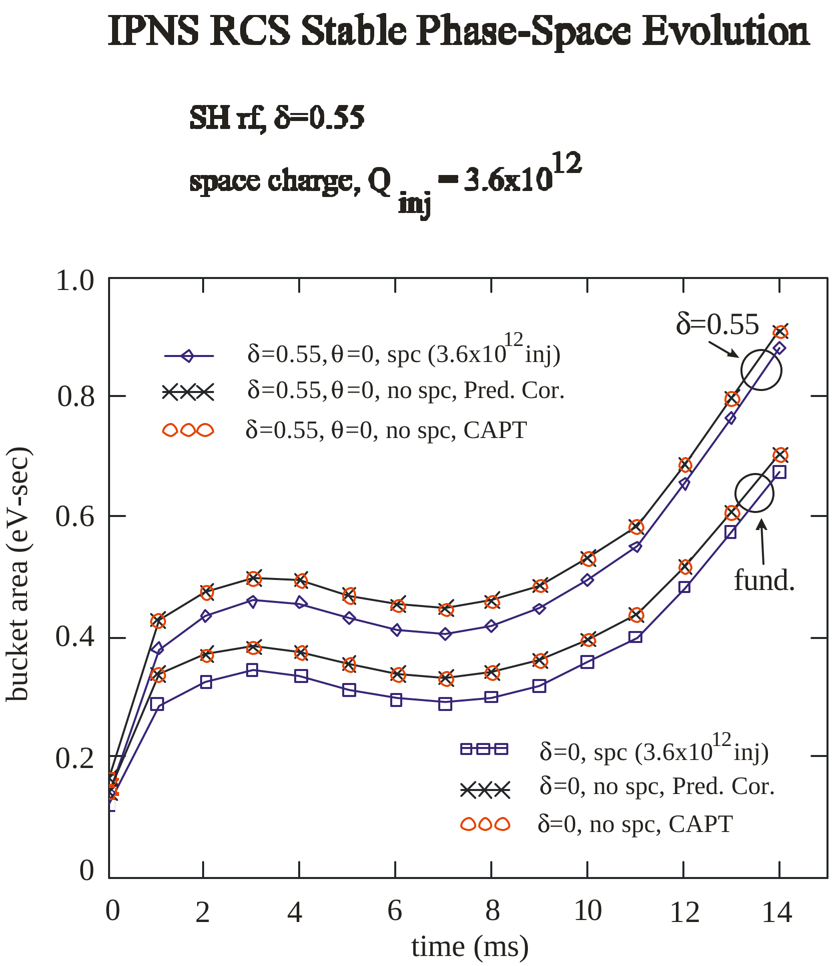




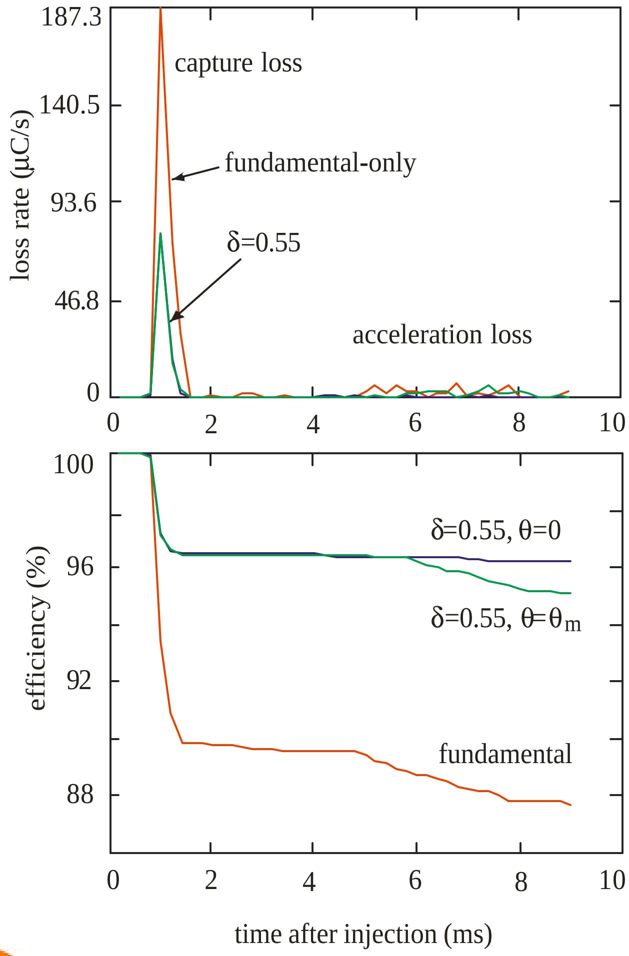
Simulation results with second harmonic (SH)

- Simulation with fund. only and SH, zero phase
- Comparison of predictor-corrector model and CAPTURE_SPC† (also second order) with no space-charge yields essentially identical results.

†Y. Cho, E. Lessner, K. Symon, Proc. EPAC, 1228(1994).



Loss and Efficiency
capture and early acceleration



- Initial testing with SH, try SH early then switch to fundamental frequency program
  - J. Norem, et al., IEEE Trans. NS, 30, 3490(1983).
  - CB PS rise time 2.5 ms
- Initial phasing tied to fundamental
- New ferrite not needed for this

For simulations:
ΔE_{inj}=0.4 MeV
$\Delta p/p$=0.4%

J. Norem's proposal

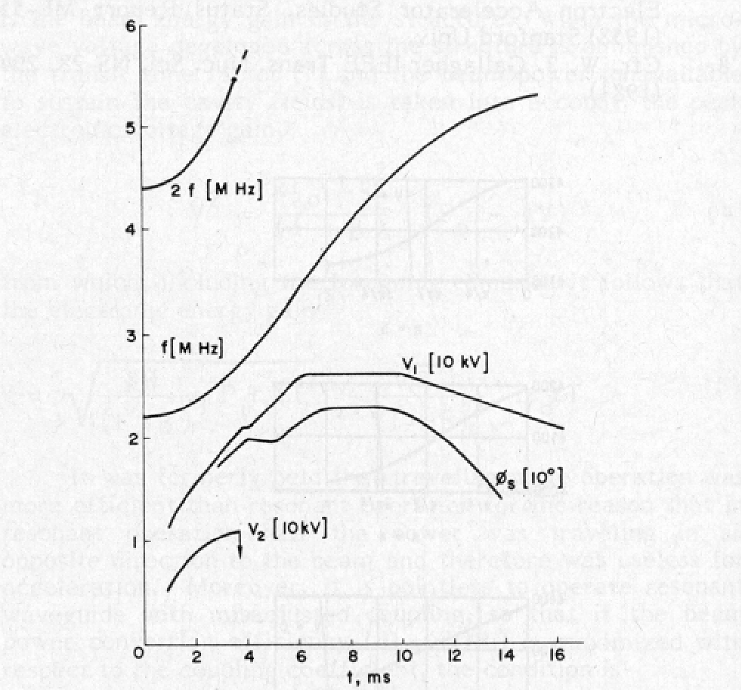


Fig. 2. Voltage and frequency programs for the two harmonics.

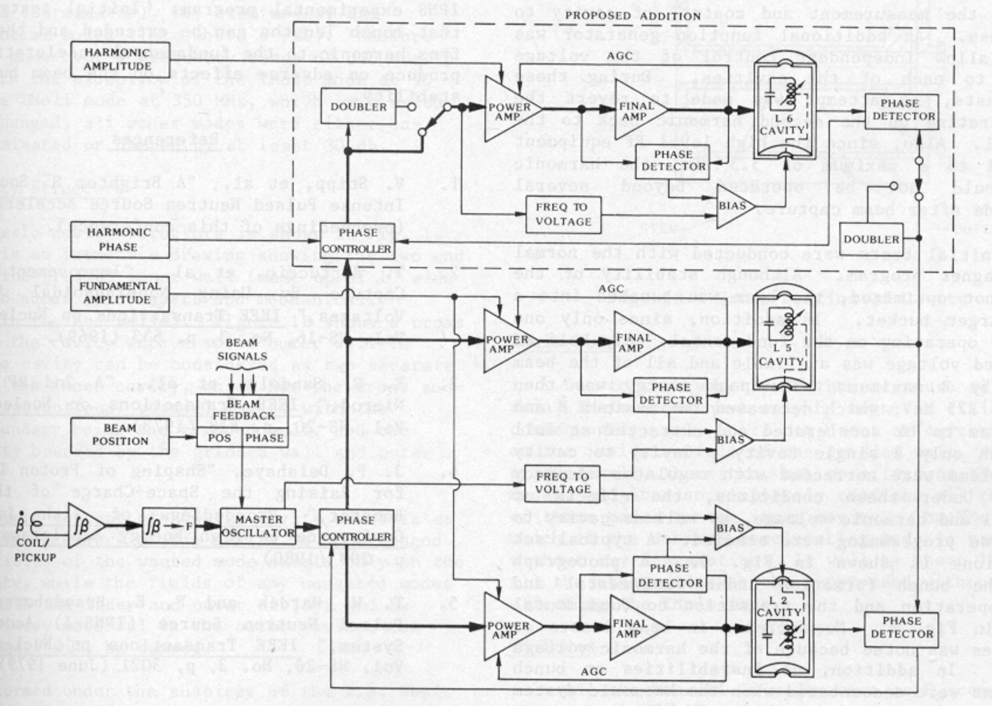
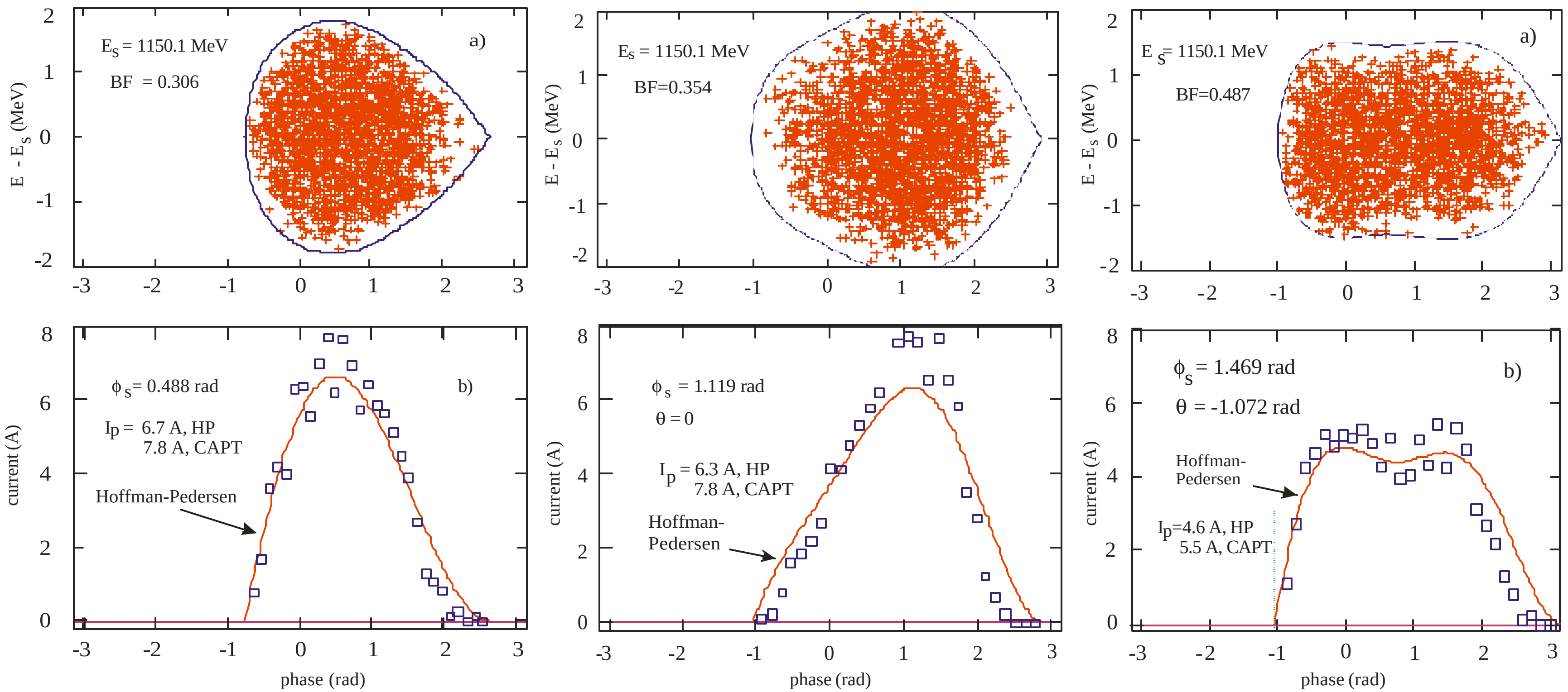


Fig. 4. Block diagram of the existing and proposed accelerating systems.

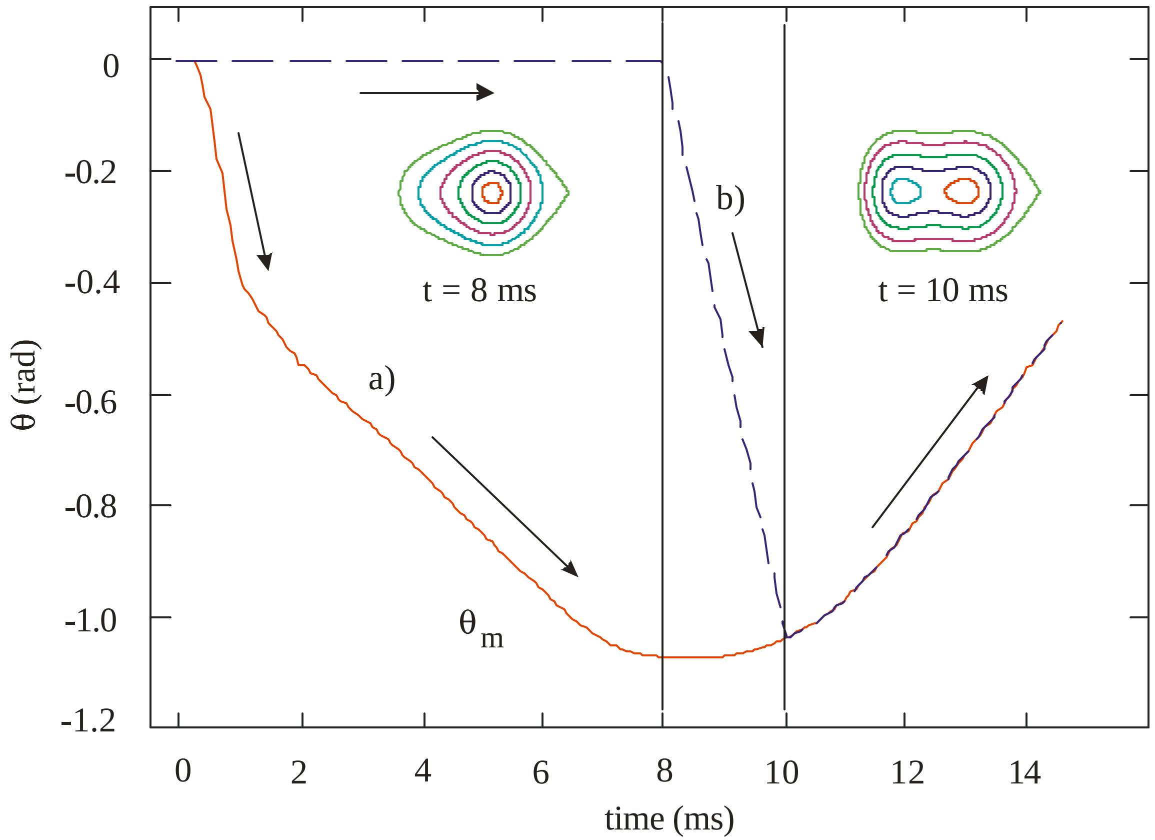
- PM not included!

Comparison of CAPTURE_SPC and HP elliptical line densities



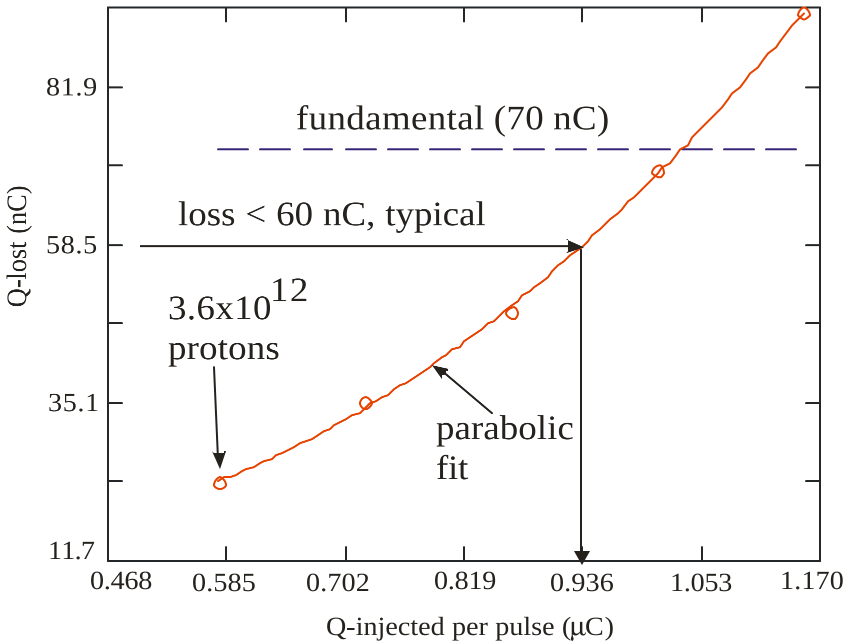
With new ferrite, can extend SH for the full acceleration cycle (4.4-10.3 MHz)

possible phasing strategies--

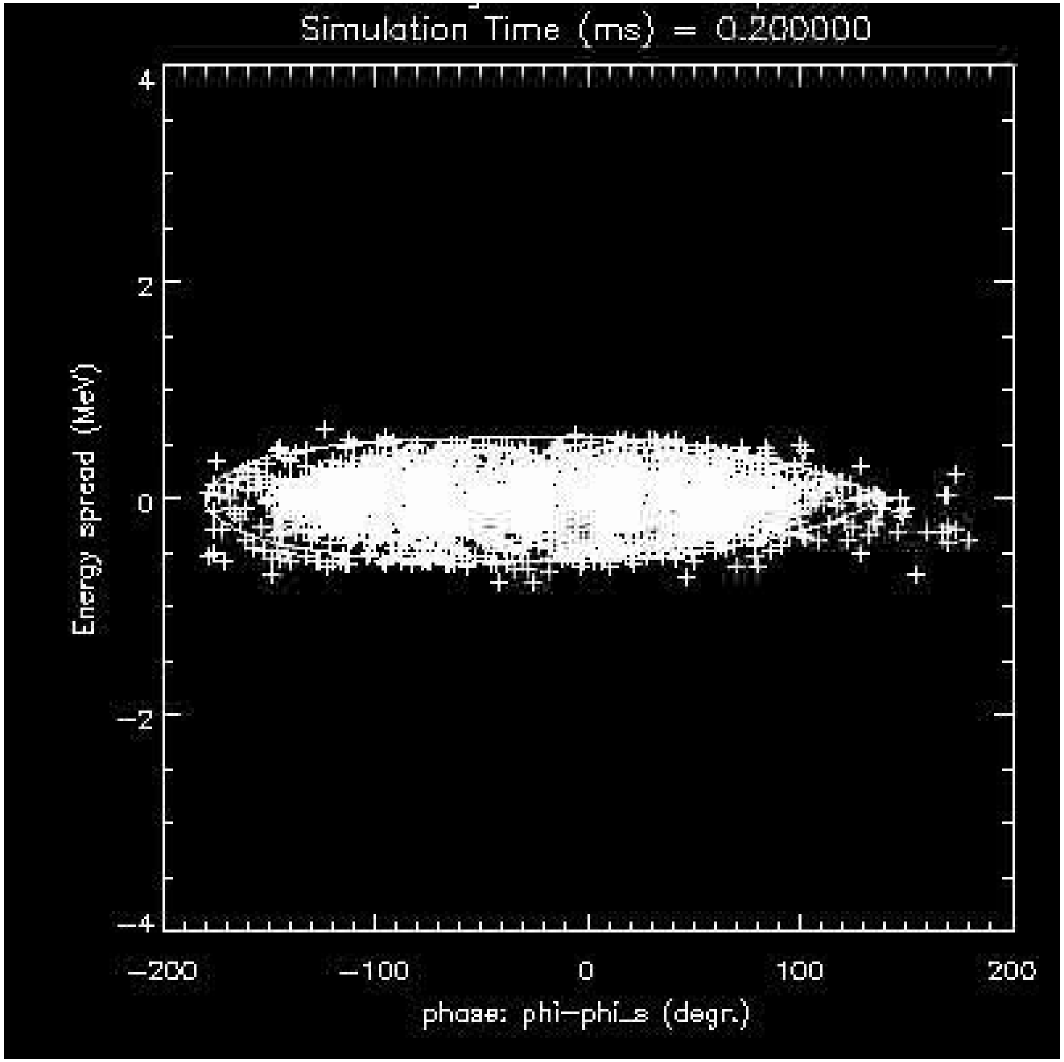


Simulation suggests current increase as much as 60 percent with full SH

Loss limit operation predicted by CAPTURE_SPC
using θ-ramp from 8-10 ms
(δ=0.55)



CAPTURE_SPC simulation for full SH and phase ramp



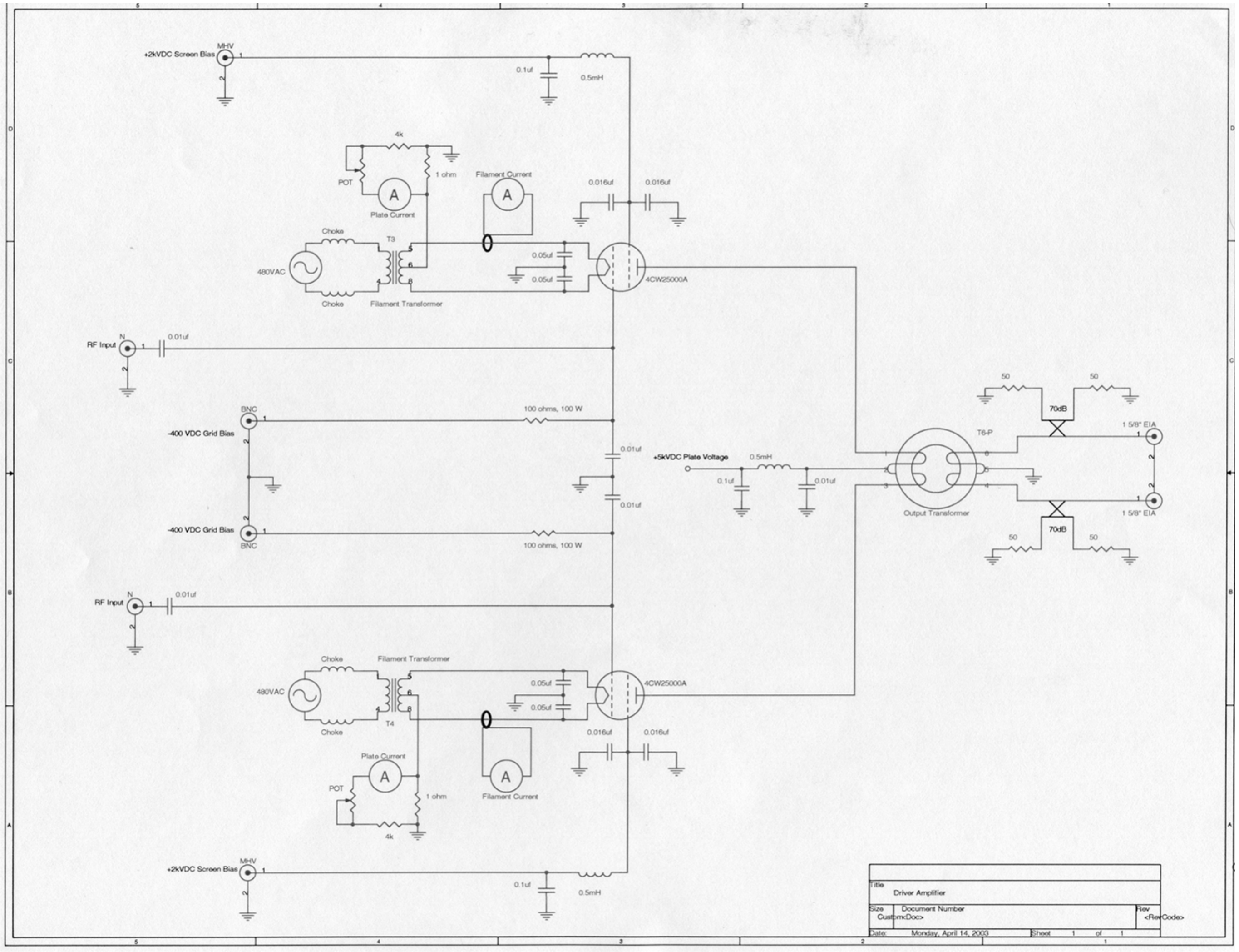
3rd cavity operational issues

- How far can present ferrite be pushed (~6 MHz)?
- Cavity response time (relatively slow CB PS) for frequency switch over
- Idling—once 3rd cavity is in, can we turn it off without too much parasitic losses
- Stability—with SH, will the PM scrambler still be necessary?
- Phasing—determine the optimum phase vs. t
  - Hopefully we can glean some of this from ISIS studies

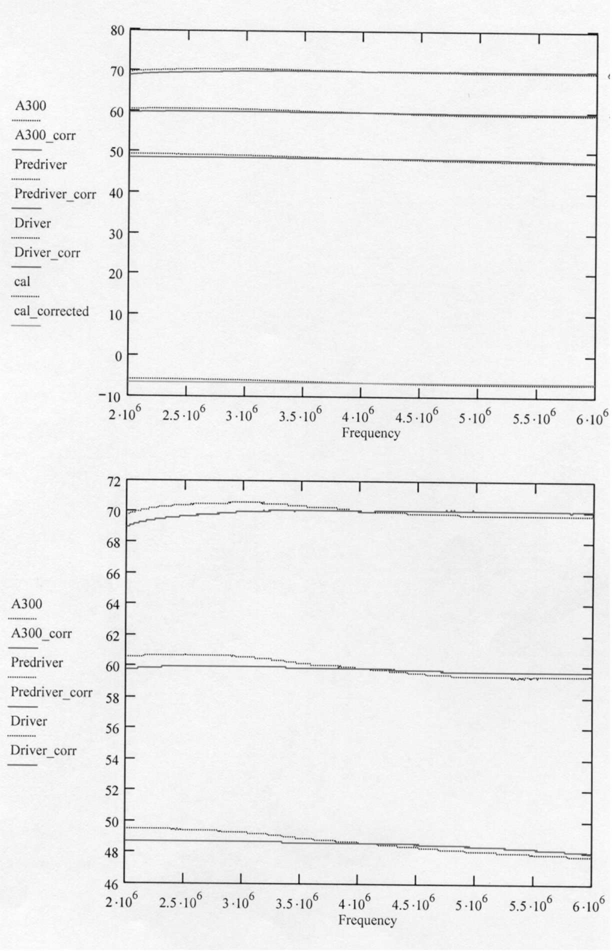
Recent results

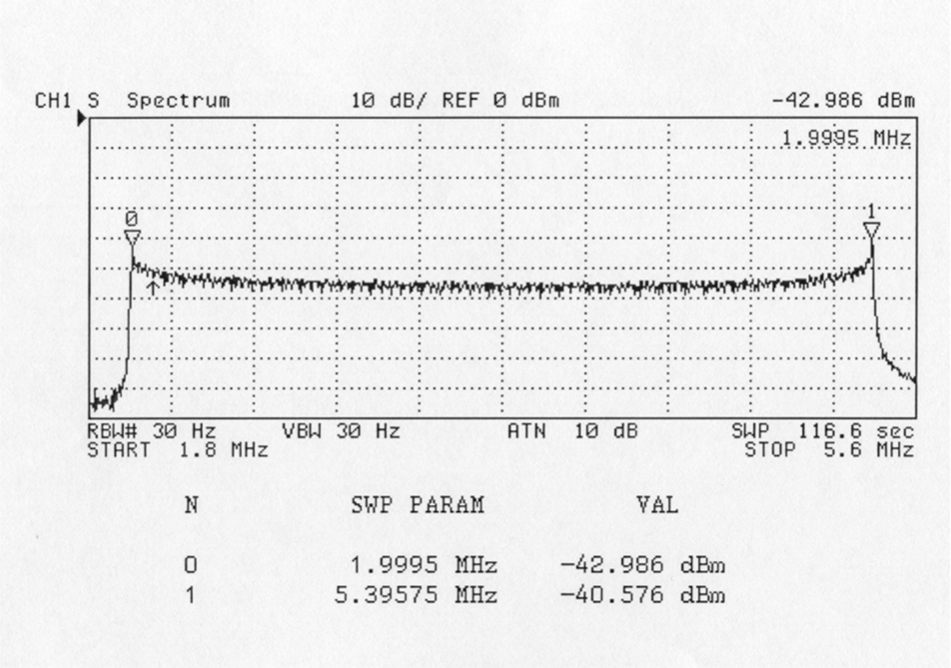
- Good news—Pre-driver and driver are working up to design power levels~15 kW into 50-Ω loads.
- Bad news is the final is not completed yet
- Good news is that the final is almost complete as later pictures will show
  - Still need crowbar (talking to DTI—fast opening sw.)
  - Filament choke using ferrite design is presently being constructed in our shop

Driver Schematic

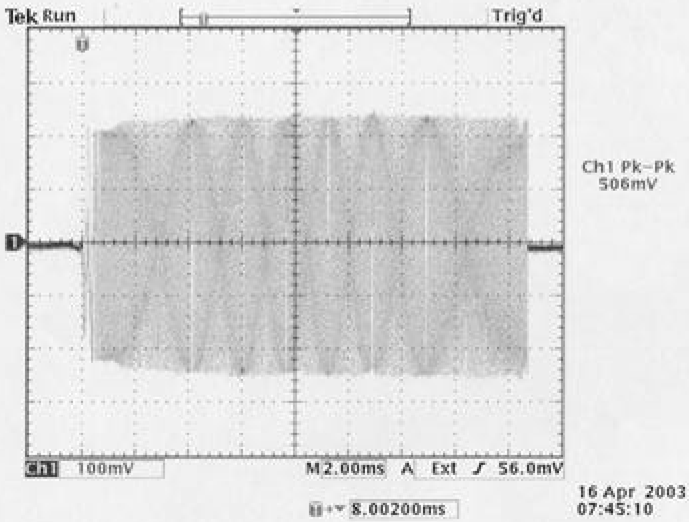


Driver Data–amplitude vs. frequency

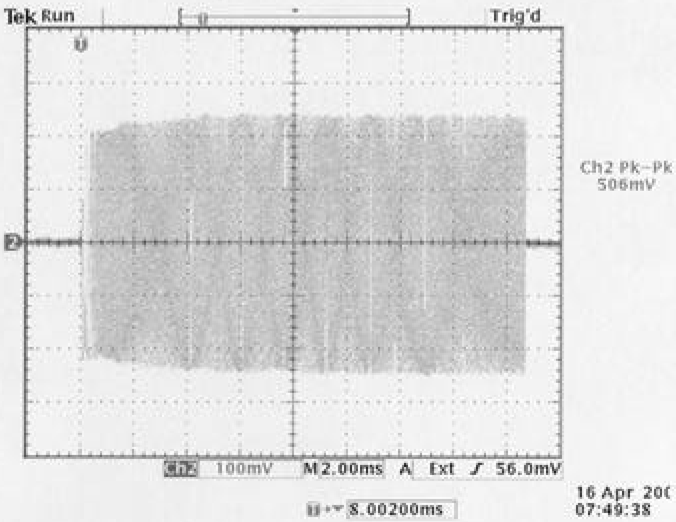




Driver Data–amplitude vs. time

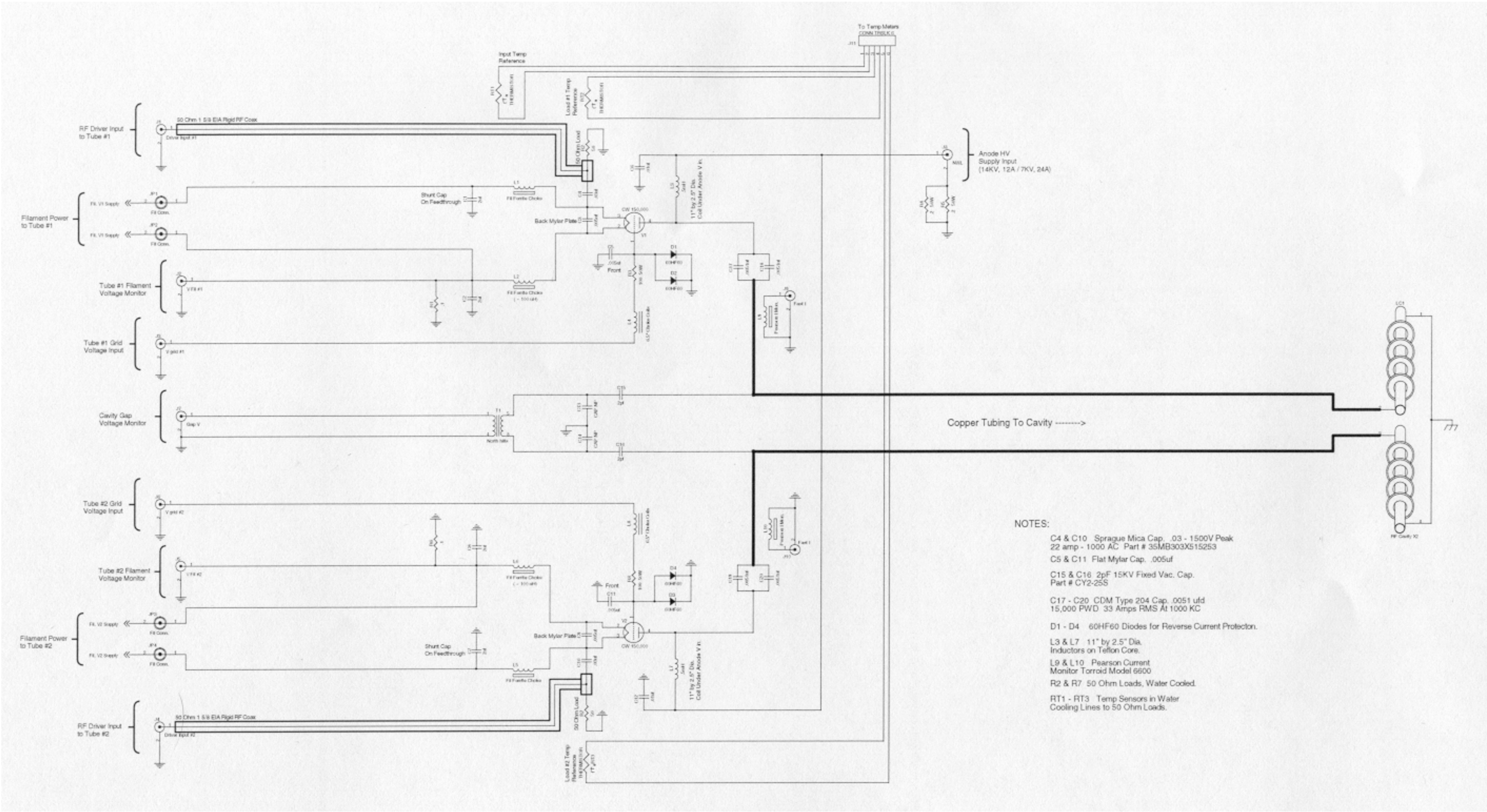


Driver Tube A, 70 dB attenuation.

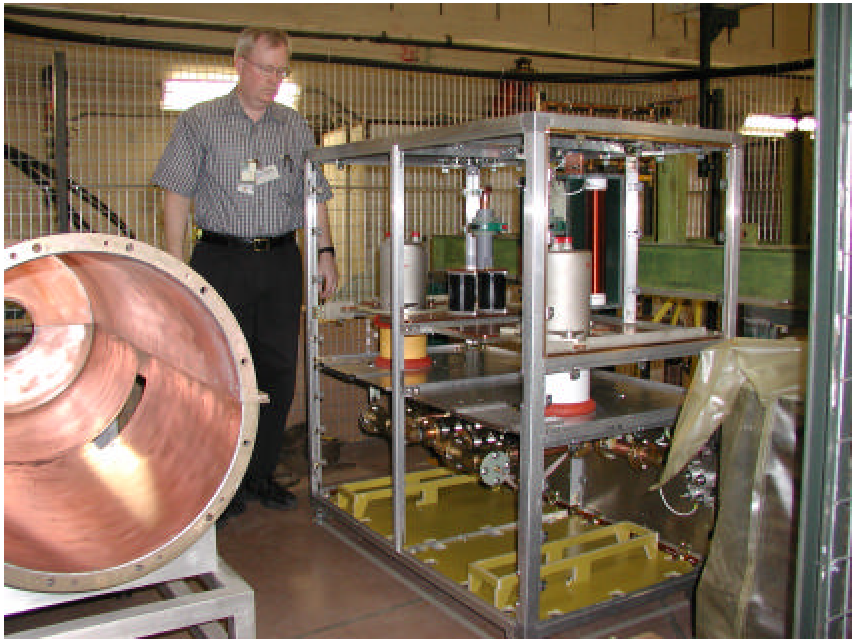


Driver Tube B, 70 dB attenuation.

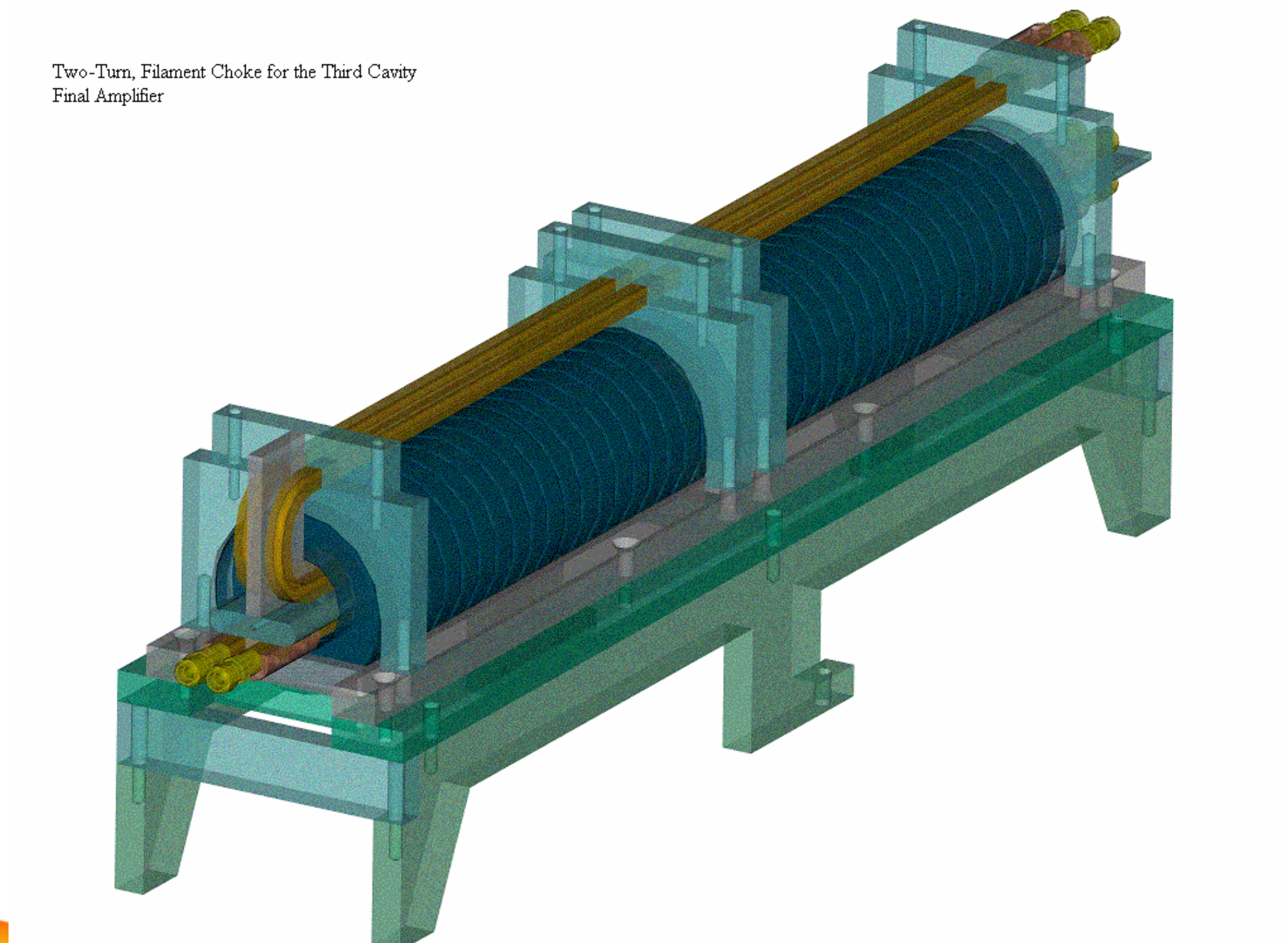
Final schematic



Final Cabinet is now in the RF Test Stand Area

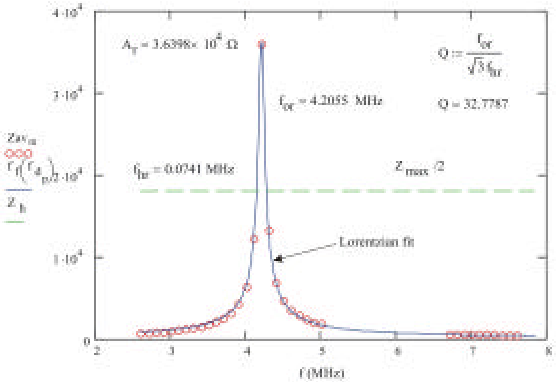


Two-turn ferrite filament choke



Filament choke prototype data

4x7 turn .289" prototype choke coil, data supplied by J. Russell, CCI, 3/5/03



$$f_f(x) := \left[\frac{A_r}{\sqrt{1+\left[\frac{2\cdot(x-f_{or})}{f_{hr}}\right]^2}}\right] \qquad N_p := 525 \qquad p := 0..N_p$$

$$df_m := (fm_1 - fm_0).1 \qquad df_m = 0.01 \qquad fd_p := fm_{N_{start}} + p\cdot df_m \qquad fm_{N_{start}} = 2.6$$

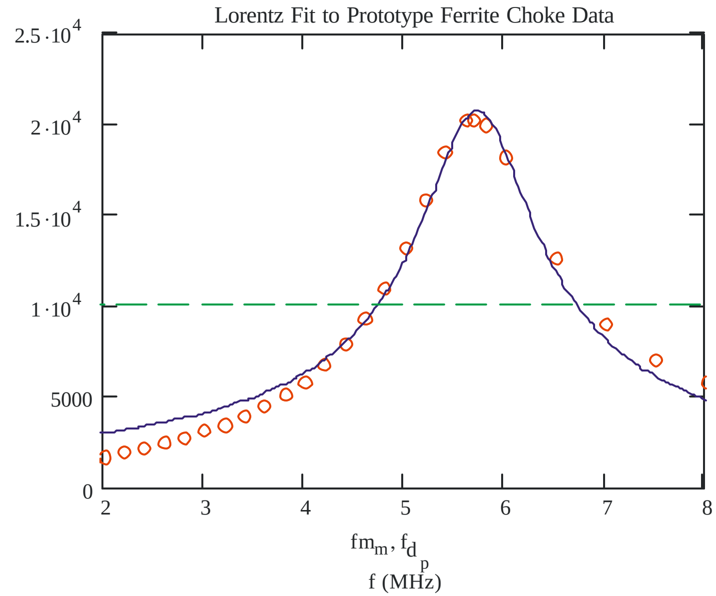
$$err := \sqrt{\frac{\sum_m \left(Zav_m - f_f(fm_m)\right)^2}{N_m - 1}} \qquad err = 124.037\ \Omega$$

$$f_{res} := f_{or}\cdot 10^6 \qquad \omega_{res} := 2\cdot\pi\cdot f_{res}$$

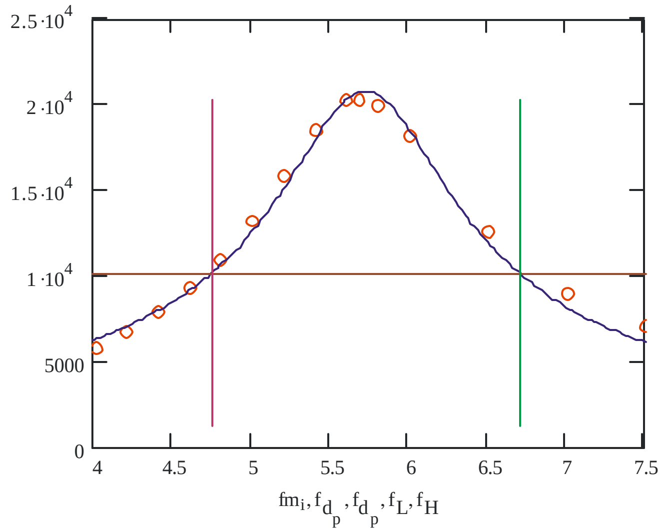
using the calculated value of capacitance from the series combinations, assuming εr=4 (34 pF):

$$C := 34\cdot 10^{-12}\ F \qquad L := \frac{1}{\omega_{res}{}^2\cdot C} \qquad L = 4.2124\times 10^{-5}\ H$$

Ferrite filament choke—impedance stays inductive, is not as peaked, and has a significant resistive component



$f_{t1} := 4$ $\quad f_{t2} := 7.5$ $\quad f_L := 4.75$ $\quad f_H := 6.7$ $\quad \Delta f := f_H - f_L$ $\quad \Delta f = 1.95$



$f_{or} = 5.7247$ $\quad f_{res} := f_{or} \cdot 10^6$ $\quad \omega_{res} := 2 \cdot \pi \cdot f_{res}$

using the calculated value of capacitance assuming a 42 microHenry inductance:

$Q_{meas} := \frac{f_{or}}{\Delta f}$ $\quad Q_{meas} = 2.9357$

$C := 4.8 \cdot 10^{-12}$ $\quad L := \frac{1}{\omega_{res}^2 \cdot C}$ $\quad L = 1.6102 \times 10^{-4}$

RF Test Stand Cabinets

SS, PreDriver, and Driver Amplifiers

- Final Grid and Filament PS

RF Test Stand
—inside the ZGS tunnel

RF Final Diagnostics

- Plate current on each tube (shunt resistor, 0.1 Ω, 50 W)
- Total plate current return to the NWL PS (shunt resistor, 0.1 Ω, 100 W)
- Fast current on each side of the gap (Pearson CTs)
- Gap voltage (cap. divider)
- Thermocouples on both 10 kW, 50-Ω loads at the final input for calorimetry (RTDs)

Acknowledgement

This work would not be possible without the dedication and hard work of the IPNS Accelerator Operations Group; as well as support from the ANL IPNS and MSD Divisions, and the DOE.