MI RF SYSTEM UPGRADE
for
PROJECT X

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Scope

- **Summary of MI RF System Parameters**
- **Diagram of existing MI RF Cavity**
- **New Cavity Design**
- **Beam Loading Compensation**
- **Recycler RF**
- **Four Year R&D Plan**
- **Conclusion**

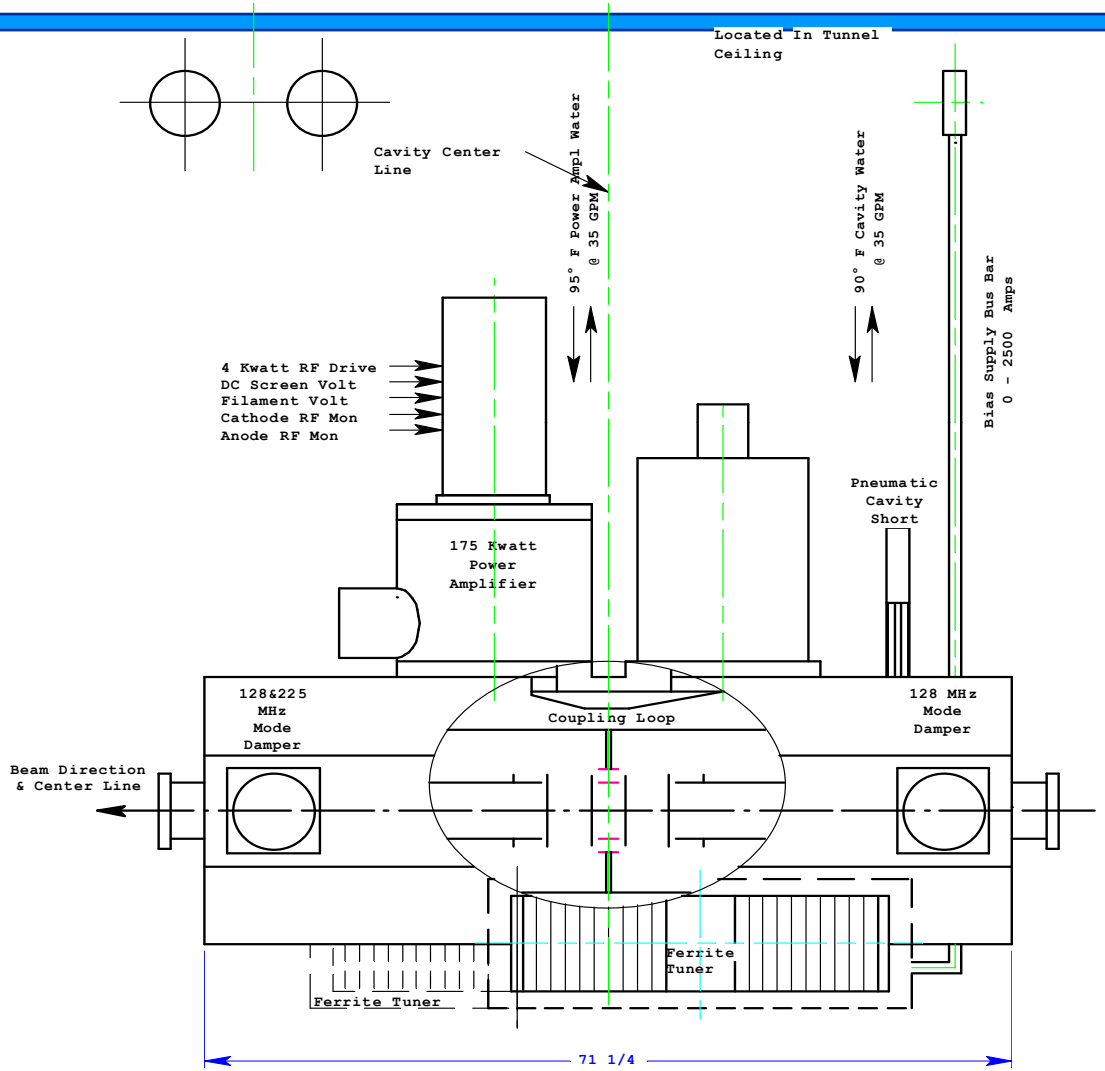
MI RF System Requirements

RF Parameter Table

	Present Main Injector	Project X Two PA Cavity	Project X New Cavity Design
Harmonic Number	588	588	588
Number of Filled Buckets	492	548	548
Frequency:	52.8114-53.104 MHz	52.8114-53.104 MHz	52.8114-53.104 MHz
Acceleration Ramp Slope:	205 GeV/s	240 GeV/s	240 GeV/s
Beam Intensity:	4.0E13 Protons	1.6E14 Protons	1.6E14 Protons
Beam Accelerating Power:	1.312 MW	6.144 MW	6.144 MW
Number of Accelerating Cavities:	18	20	18
Cavity R/Q:	104	104	25
Cavity Power Loss per Cavity	56.5 kW	56.5 kW	450 kW
Accelerating Power per Cavity (beam):	72.89 kW/Cavity	307.2 kW/Cavity	341.3 kW/Cavity
Maximum cavity Accelerating Voltage:	235 kV/Cavity	235 kV/Cavity	300 kV/Cavity
Accelerating voltage required: $V\sin\phi_s$	2.27 MV	2.66 MV	2.66 MV
Total Accelerating Voltage Available:	4.23 MV	4.7 MV	5.4 MV
Total Peak Amplifier Power Required:(beam + cavity)	129.4 kW	363.7 kW	791.3 kW

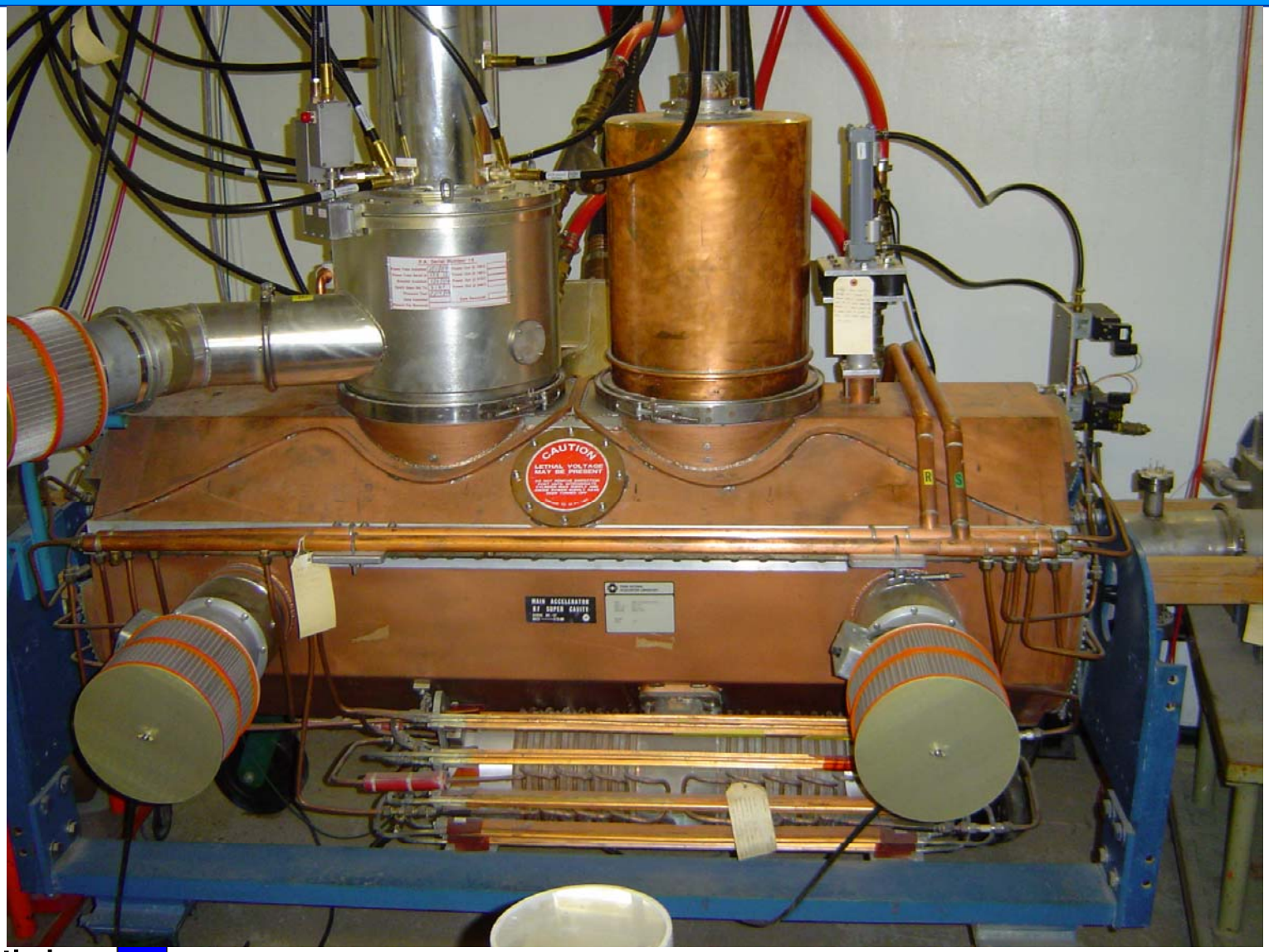
Two PA's on existing MI Cavities

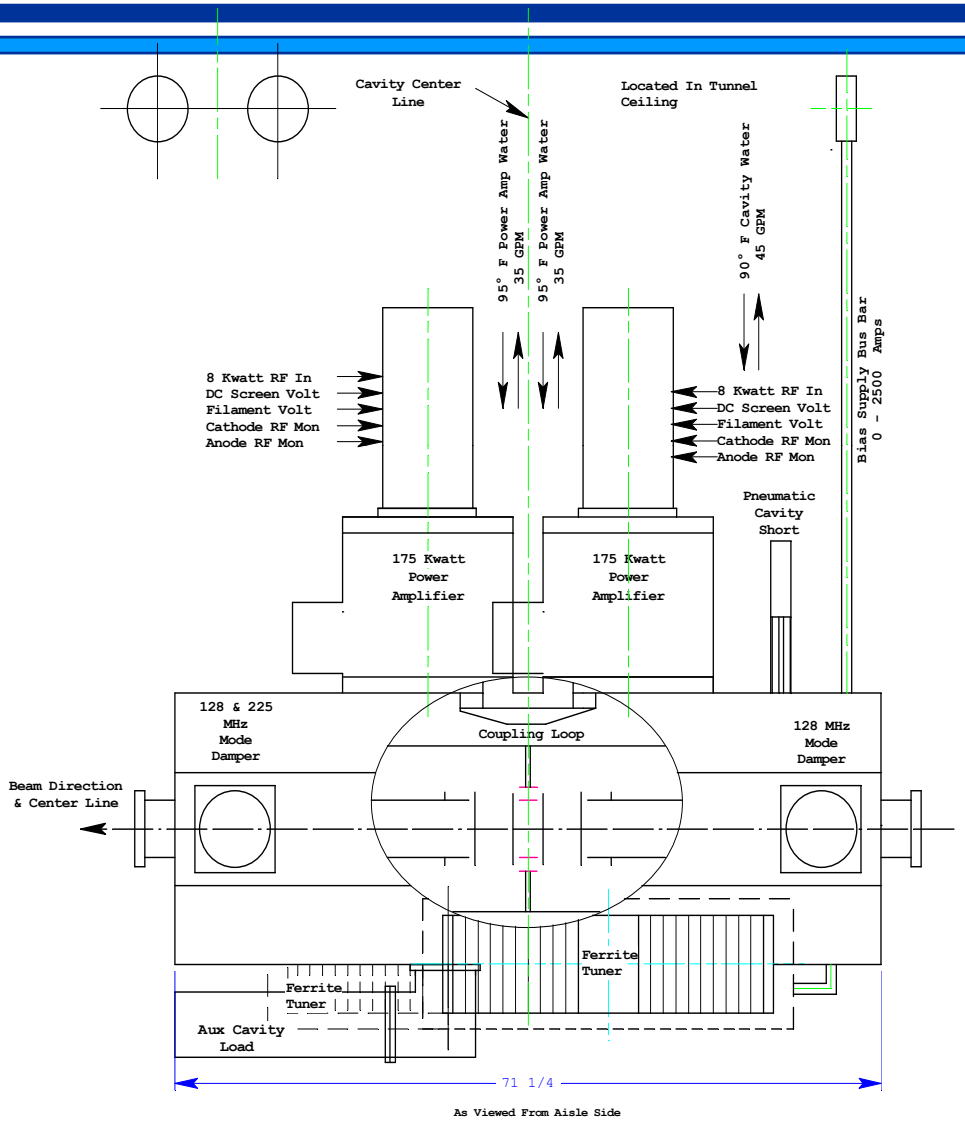
- **Not sufficient power to accelerate 1.6E^{14} protons.**
- **Does not increase cavity voltage, only available current.**
- **Duty factor limited to ~ 50 % due to cooling limitations in present cavity design.**
- **PA Power output rated at 175 Kwatts per PA, total of 350Kwatts per cavity for two PA cavity.**
- **Project X requires ~ 364Kwatts for beam + Cavity**
- **Need additional power for beam loading compensation.**
- **Not a suitable solution for Project X**



Present Main Injector Cavity

Standard MI RF Cavity





Modified Main Injector Cavity for Two Power Amplifiers

New RF System

53MHz Specifications

- Intensity of 1.6E^{14} per MI cycle
- Maximum ramp rate of 240 GeV/s
- Cavity peak voltage of 300 kV
- 18 RF stations - same as current system
- Frequency sweep: 52.8114 MHz to 53.104 MHz

106MHz Specifications

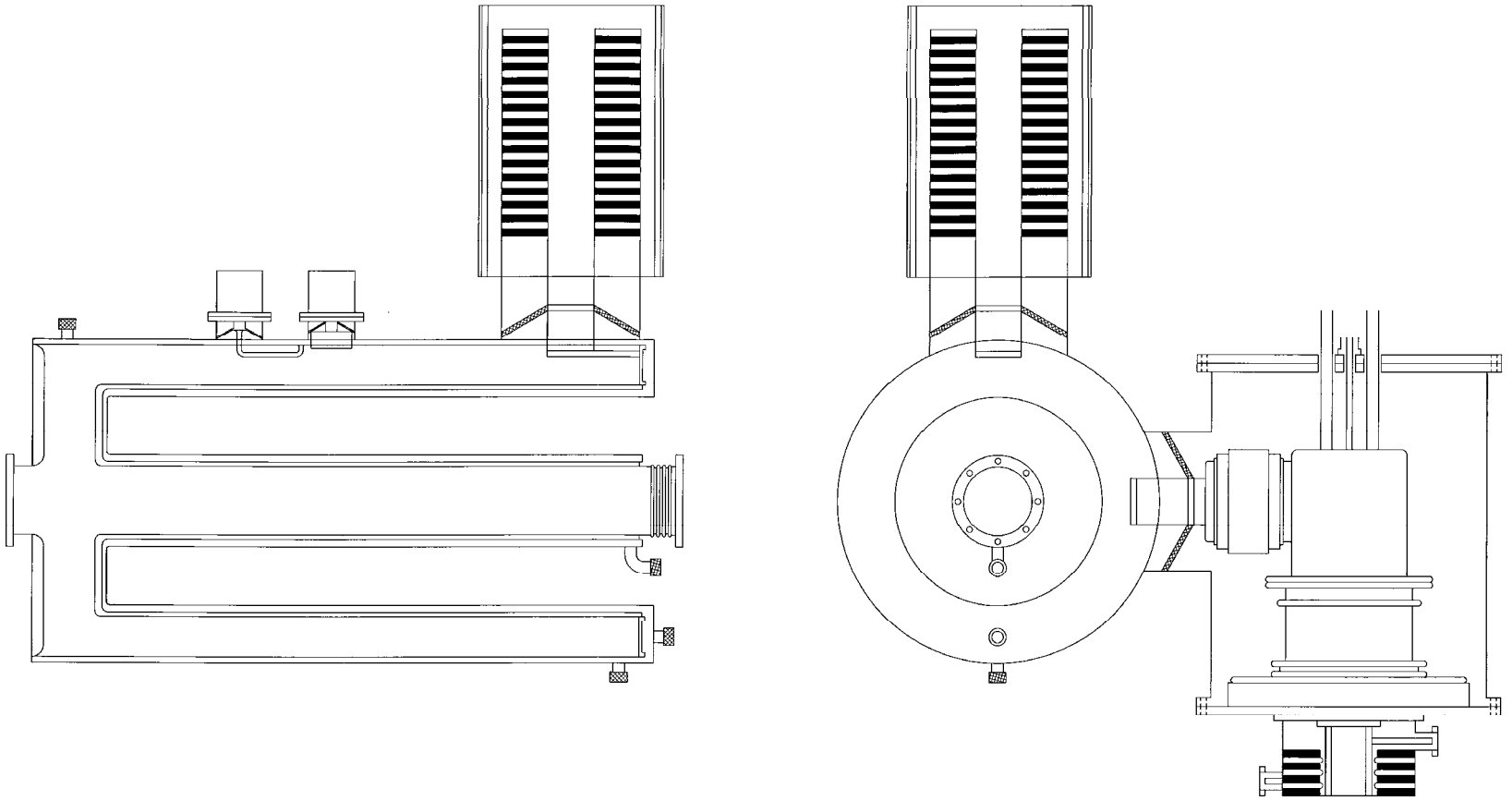
- Intensity of 1.6E^{14} per MI cycle
- Maximum ramp rate of 240 GeV/s
- Cavity peak voltage of 250 kV
- 5 RF stations
- Frequency sweep: 105.623MHz to 106.208MHz

Courtesy: D. Wildman Proton Driver Director Review March 2005

Cavity Parameters

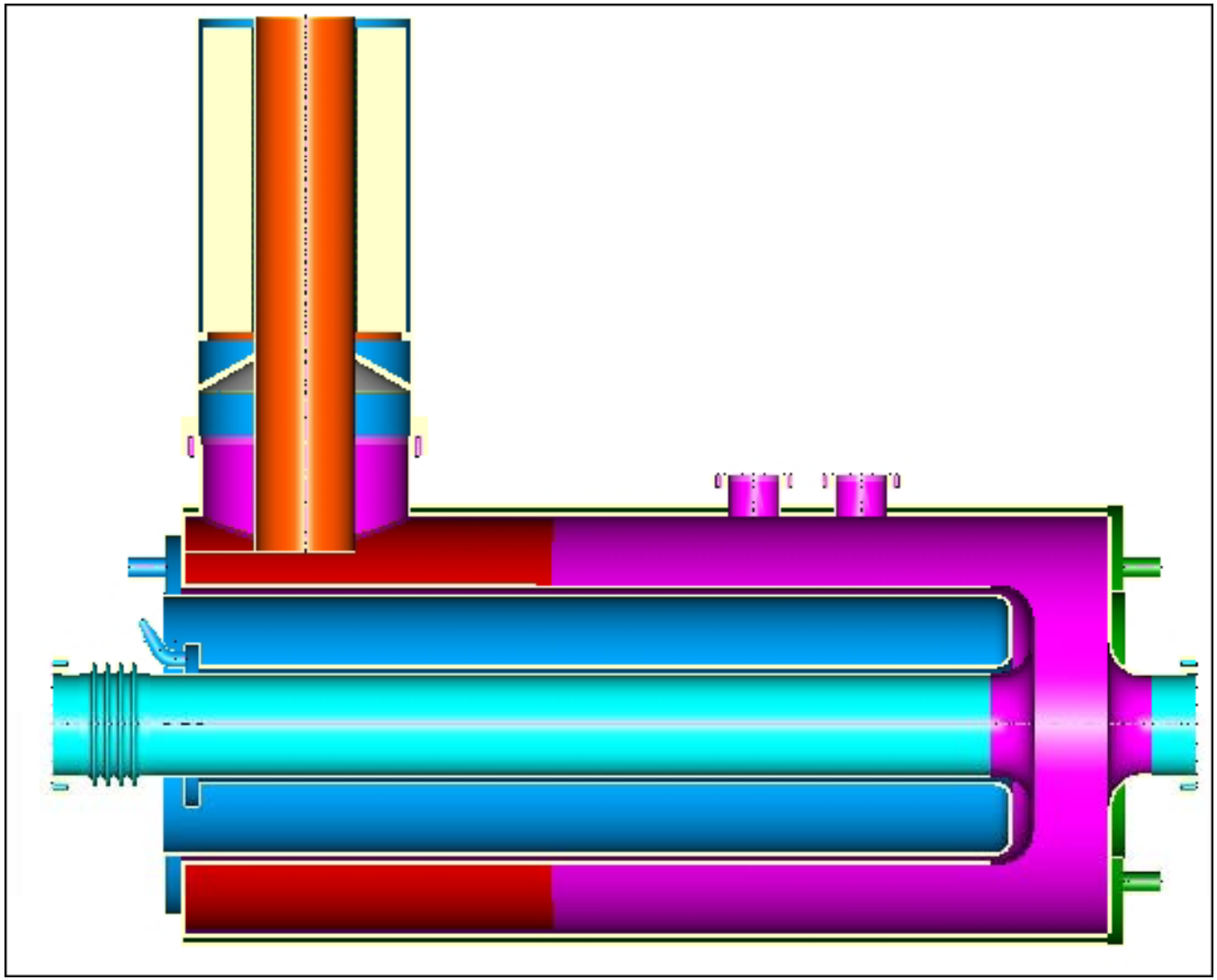
- **Rs = 100 K**
- **Q = 4000, from copper coated stainless construction**
- **Rs/Q = 25, low Z transmission line**
- **Perpendicularly biased garnet tuner**
- **Present RF system will be driver for new PA**
- **Available PA Power Tetrodes:**
  - CPI Eimac 8973 (1 Mwatt)
  - Thales TH525 (1.5 Mwatt)

Cavity Design



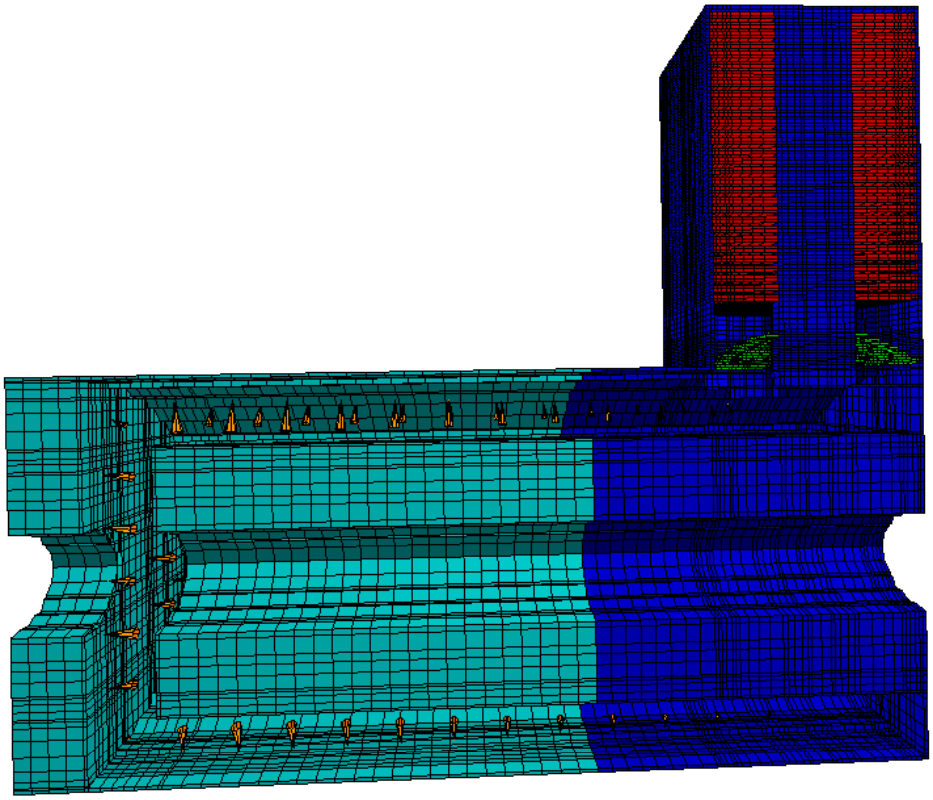
Courtesy: D. Wildman Proton Driver Director Review March 2005

Cavity Design



Courtesy: D. Wildman Proton Driver Director Review March 2005

Cavity Design



Blue: copper
Teal: stainless steel
Green: ceramic window
Red: ferrites

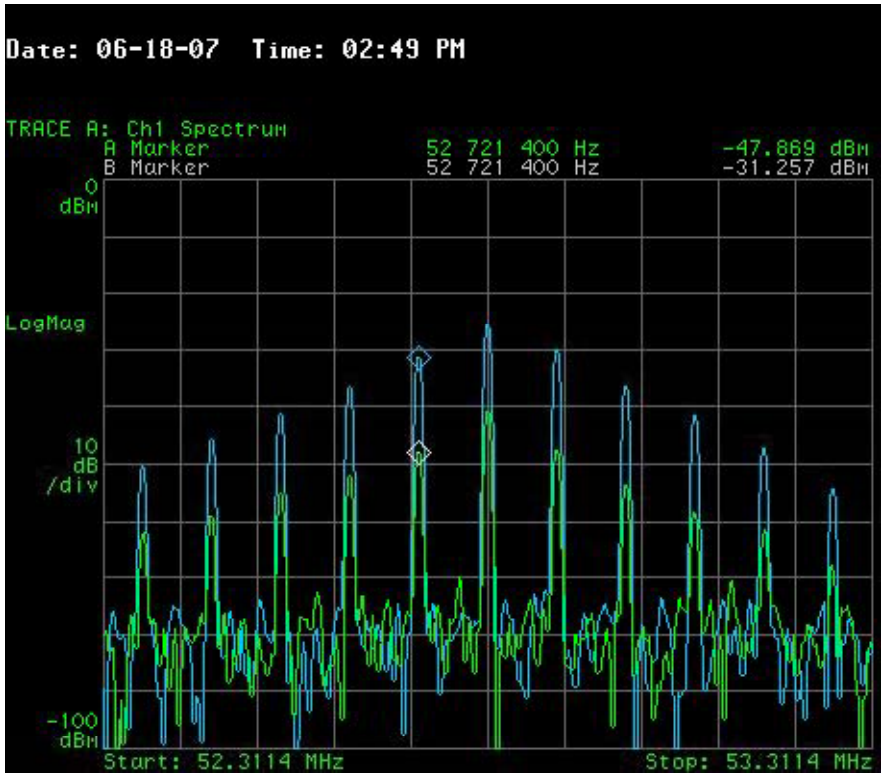
Advantages
- Perpendicular biased
- Low rf tuner losses
- Use existing bias PS

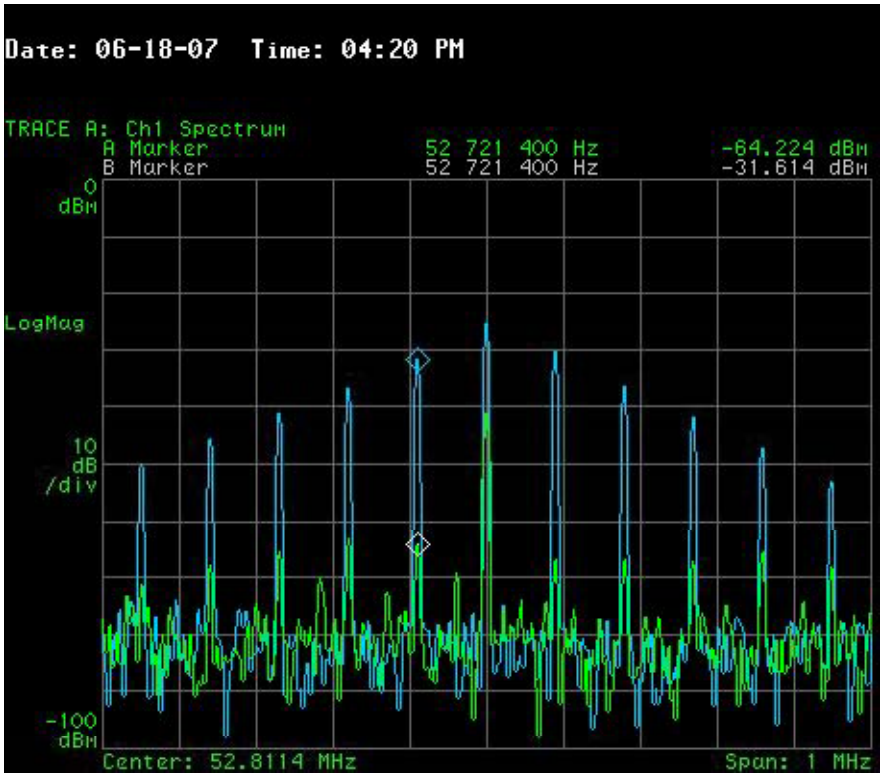
Courtesy: D. Wildman Proton Driver Director Review March 2005

Beam Loading

- **Present System utilizes:**
  - Direct rf feedback
  - Feed forward (one turn delay)
  - Digital comb filter presently under construction, proof of principle has been demonstrated on existing MI RF station 2.

Comb Filter Study MI Station 2

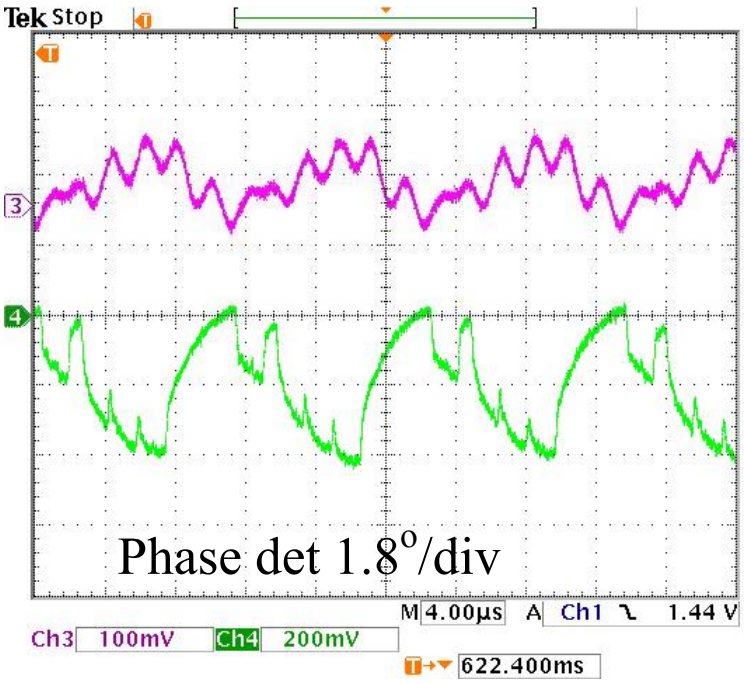




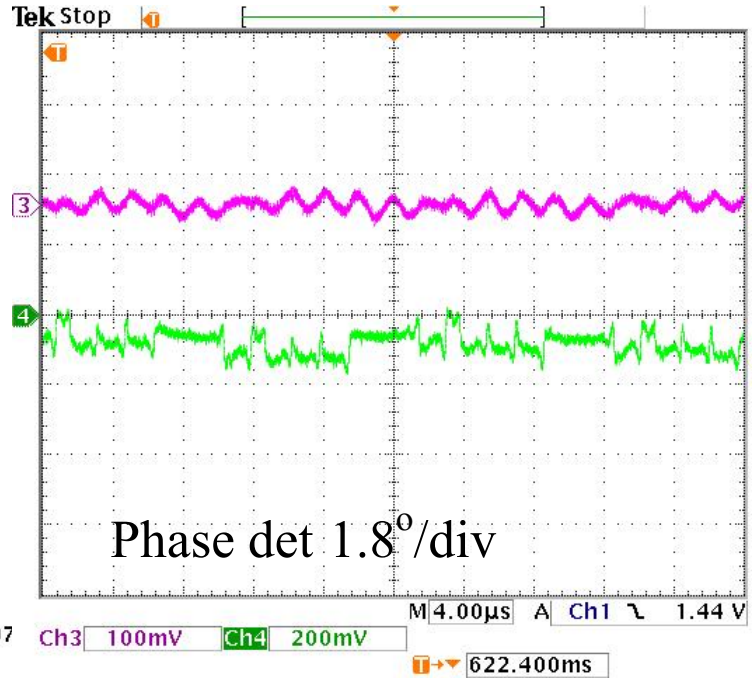
Direct + Feed forward 1st batch @ injection on RF Gap Monitor.

Direct + Feed forward + Comb Filter 1st batch @ injection.

MI Station #2 BLC – Time Domain



St 2 with Direct + Feed forward BLC only.
Magenta: Detected Cavity Gap
Green: St Fout to Fback Phase det.



St2 with Direct + Feed forward + Comb BLC.
Magenta: Detected Cavity Gap
Green: St Fout to Fback Phase det.

Recycler RF

- **Specifications**
  - Main Frequency: 52.811 MHz
  - RF Voltage: 800 kV
    - 4 cavities
    - Could be similar to new MI cavities
  - Second Harmonic rf voltage: 400 kV
    - Cavity requires design from ground up
    - New PA and driver
    - 2 cavities

Four Year R&D Program

- **Year 1**

  53MHz System

  - Draw HLRF System Architecture
  - Optimize cavity design
  - Run software simulations
  - Adapt present MIRF simulation software modeling
  - Design perpendicular biased tuner
  - Design cavity mode dampers with rf windows
  - Design rf power coupling with window
  - Schedule design review at end of first year

  106MHz System

  - Start initial paper design of cavity
  - Run cavity software simulations

Four Year R&D Program

- **Year 2**
  - 53MHz System
    - Finalize mechanical drawings for construction of prototype
    - Start fabrication of major prototype cavity components
      - Cavity
      - Tuner
      - Mode dampers
      - Cavity stand
    - Assemble cavity and start low level rf cavity measurements
    - Start design of prototype power amplifier including resonator for using existing 150Kwatt MI power amplifiers as drivers.
  - 106MHz System
    - Complete cavity design
    - Schedule review

Four Year R&D Program

- **Year 3**
  - 53 MHz System
    - Finish low level cavity & tuner measurements
    - Finish design & fabrication of prototype power amplifier
    - Complete high power testing of power amplifier into load
    - Start preliminary high power testing of cavity in MI60 test station
  - 106MHz System
    - Procure parts for prototype cavity
    - Design and start fabrication of prototype high power amplifier
    - Start assembly of prototype cavity as parts become available
    - Start low level testing of prototype cavity
    - Procure components for high power amplifier

Four Year R&D Program

- **Year 4**
  - 53 MHz System
    - Complete high power testing in MI60 test station
    - Install cavity and power amplifier in MI tunnel for beam testing.
  - 106MHz System
    - Complete high power testing in MI60 test station
    - Install cavity and power amplifier in MI tunnel for beam testing.

Conclusions

- **Present 53 MHz rf cavities with two PA's not suitable for Project X.**
- **Need new rf cavities & power amplifiers.**
  - Conservative design for beam stability shown.
  - Increase R/Q to reduce cavity power loss, thus less PA power required.
- **Beam loading compensation techniques same as present system utilizing a combination of direct rf feedback, digital comb filter, and feed forward.**
- **R&D efforts should start NOW.**