High Power RF Systems in the Fermilab Linac

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Fermilab

May 3 , 2006

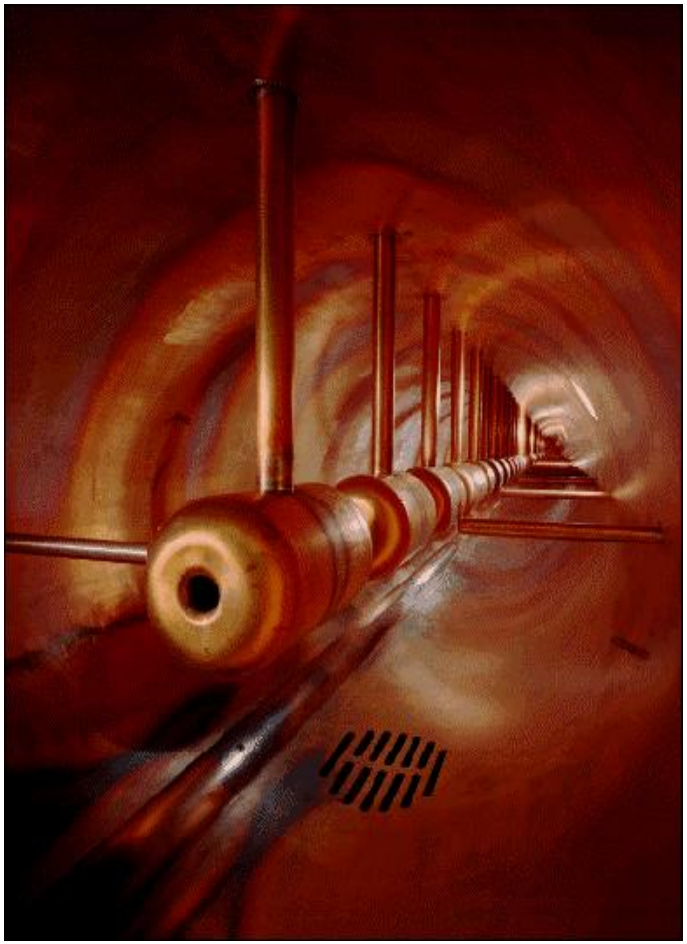
Outline of Talk

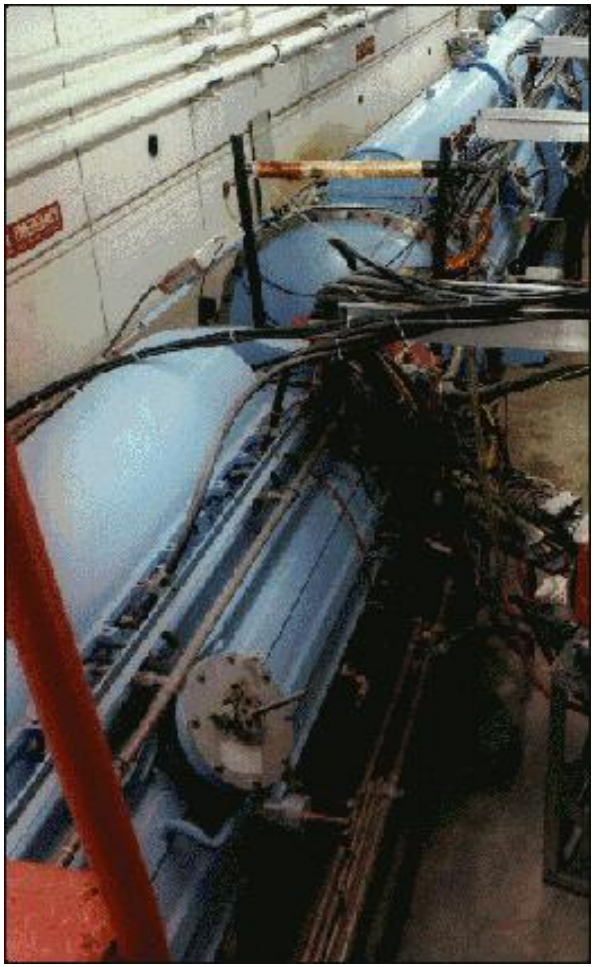
1) **Genera description of Fermilab Site**
2) **Description of the Fermilab 400 MeV proton Linac:**

   2 sections 201 MHz tubes and 805 MHz klystrons
3) **Description of High Intensity Neutrino Source (HINS) linac R&D Study.**
4) **Conclusions.**

Aerial View of Fermilab Accelerator Complex

Low Enegy Linac Section 201 MHz: Energy gain 750kV to 116 Mev Consists of 5 Drift tube Cavities



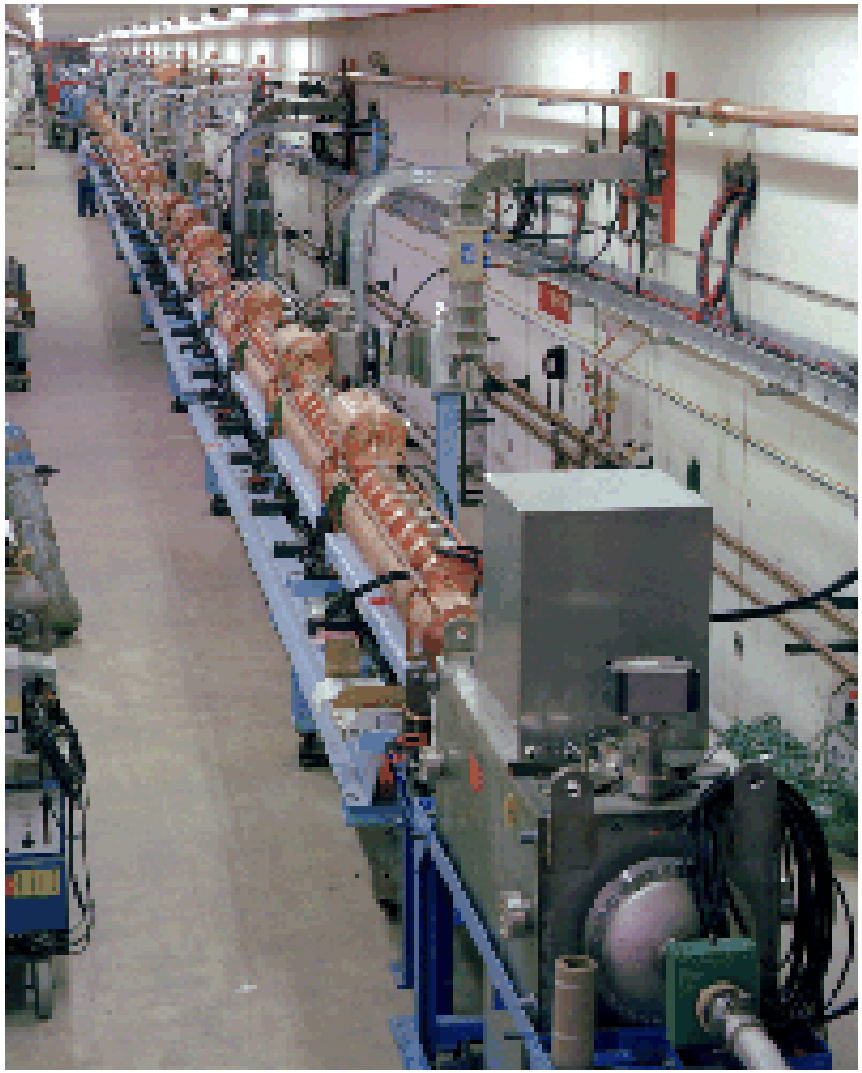


High Energy **Section**: Seven 805 MHz Side-Couple Cavity Linacs

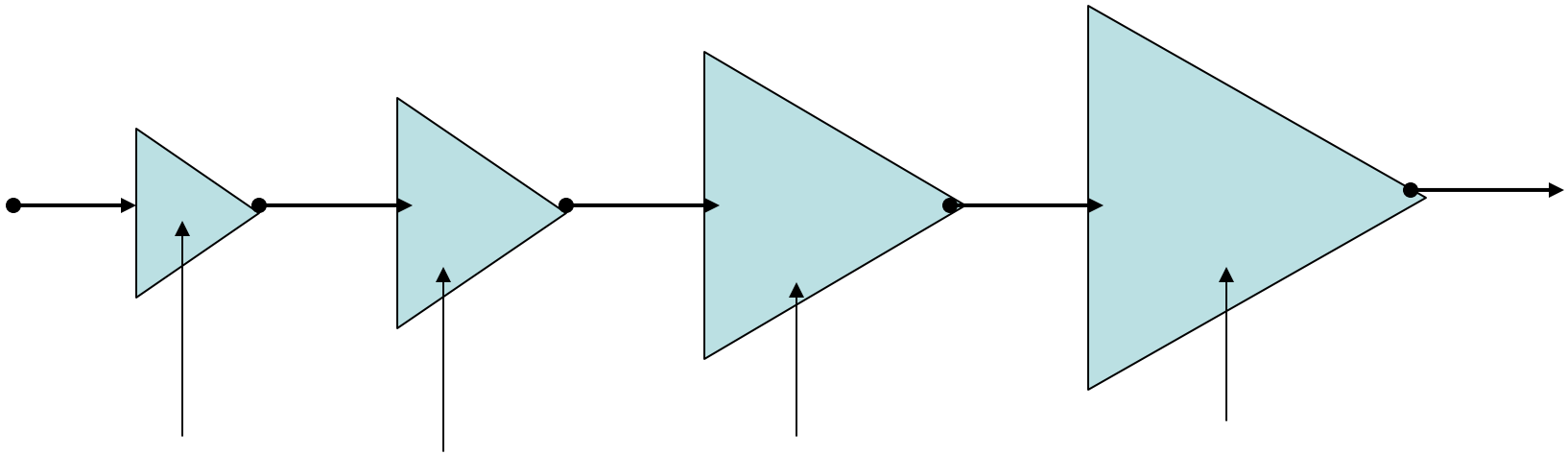
High Energy Section consists of Seven:
Four 16 cell $\Pi/2$ mode cavities coupled together with Bridge couplers in a linac module driven from one 12 MW Klystron

Energy gain: 116 MeV to 400 MeV.

Injector for 8 GeV Booster



201 MHz Amplifier Chain



30 db
Solid S
200 W

26 dB
7651
Tetrode

4 k W

34 dB
4616
Tetrode
200 kW

28 dB
7835 Triode
5 MW
Plate modulated
Feed-back,
analog and
Feed-Forward

Burle 7835 Triode Cavity Amplifier 5 MW

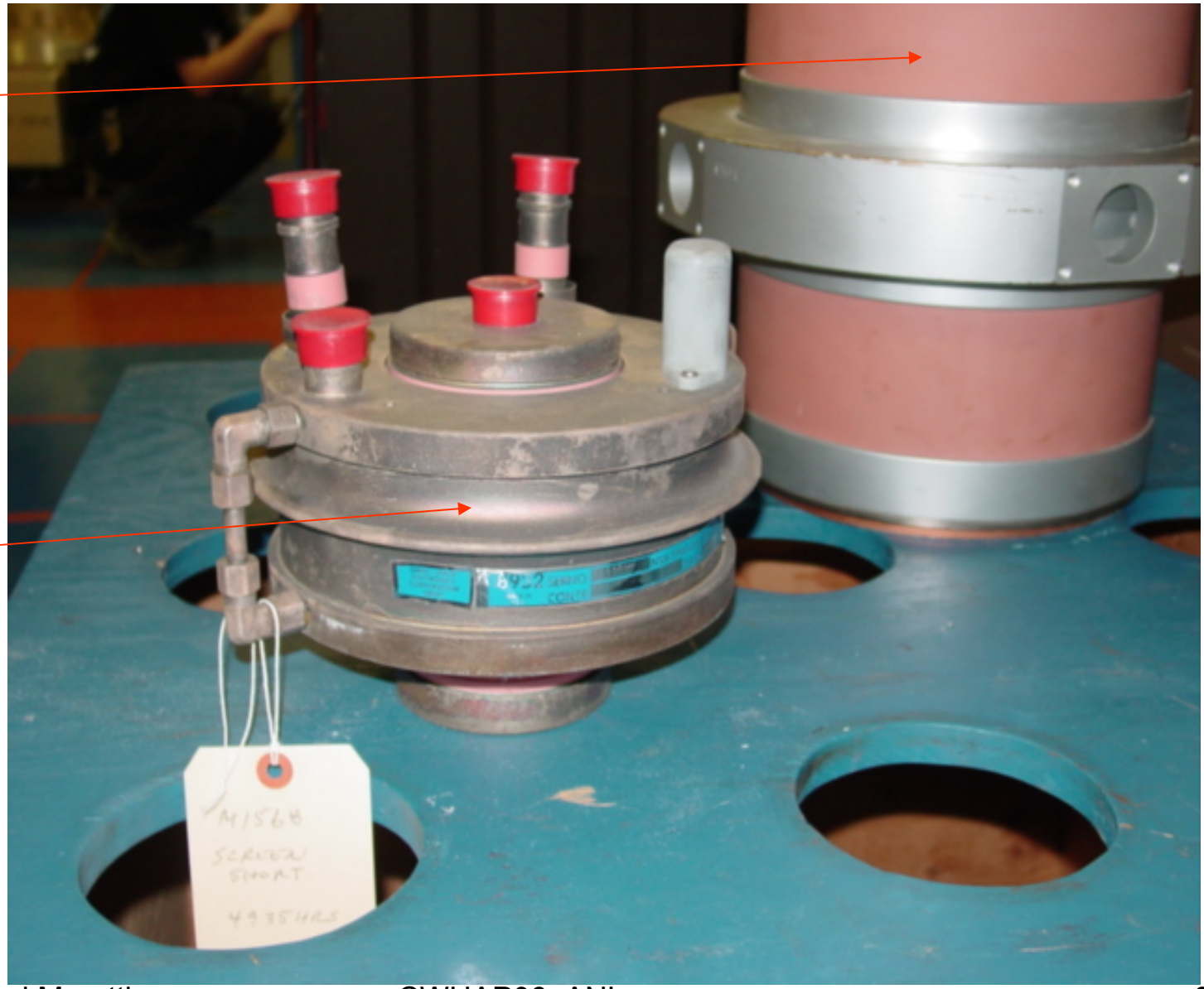
- Freq- 201.25 MHz
- RF Power- 5 MW
- Pulse- 500us, 15 Hz
- Grounded Grid
- Cathode driven
- Gain- 28 dB.
- 25-30 KV, 300 A

7835 Triode

Final Tube

5 MW

Gain-28 dB



4616 Tetrode

Driver tube

200 kW

Gain-34 dB

Details of the 7835 triode

- **Burle 7835 Triode:**
- **96 individual cathodes thoriated tungsten and 96 individual Grids**
- **All in Parallel**
- **Plate Voltage 25 to 30 kV at 300 A Heater: 1V, 6700 A D.**
- **Expensive**
- **Life time problems, mainly cathode emission life**

Spare Klystron in Its Solenoid mounted on Its Pulse Transformer

- L5859 L3Com klystron
- Developed for Fermilab on R&D contract
- 12 MW peak , 133 us, 15 Hz
- 170 k V, 155 A, 2.0 uPev
- Gain 54 dB
- Efficiency 47 %
- 5 Cavities
- Oxide Coated Cathode, 80,000 Hrs MTBF

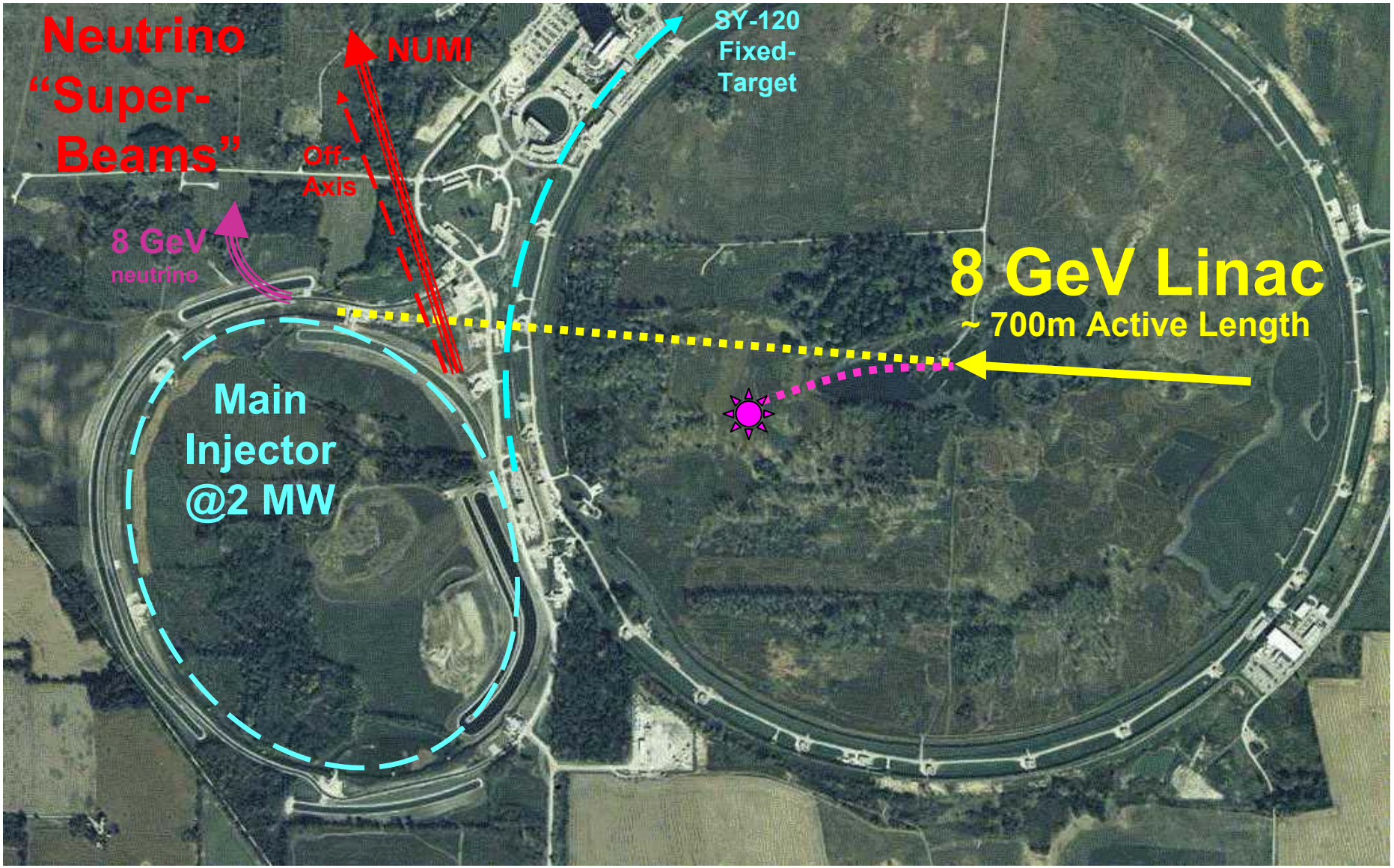
Control Racks; LL VXI Remainder VME Crates, Remotely Controlled via AcNet and EtherNet

Charging Supply and PFN

Specifications:

- 125 us at 15 Hz
- 27.5 MW peak
- 54 kW average

High Intensity Neutrino R&D Study
8 GeV H- Injection and Super Beams in the Main Injector



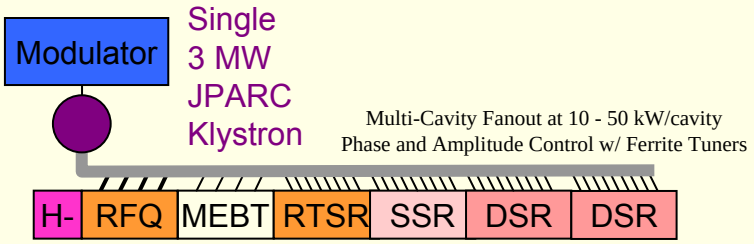
0.5 MW Initial 8 GeV Linac

11 Klystrons (2 types)
449 Cavities
51 Cryomodules

"PULSED RIA"

Front End Linac

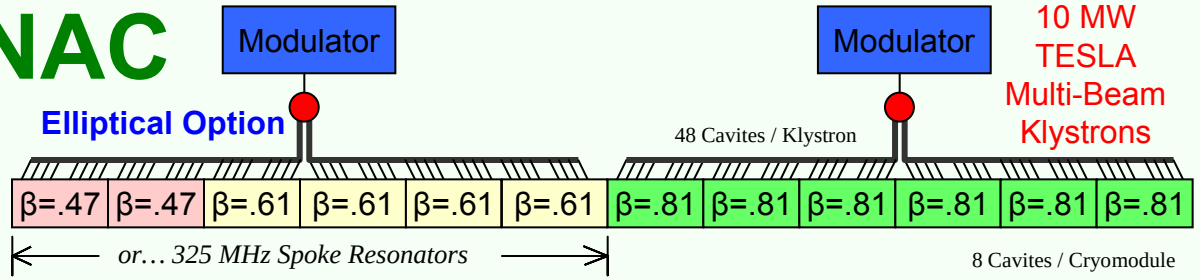
325 MHz
0-110 MeV



β<1 TESLA LINAC

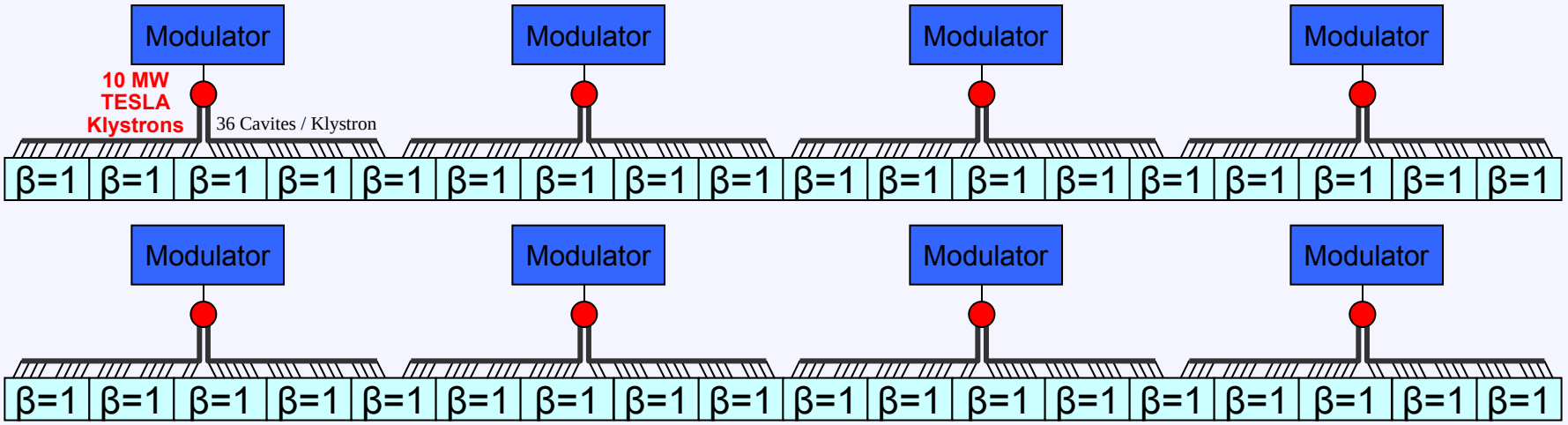
1300 MHz 0.1-1.2 GeV

2 Klystrons
96 Elliptical Cavities
12 Cryomodules

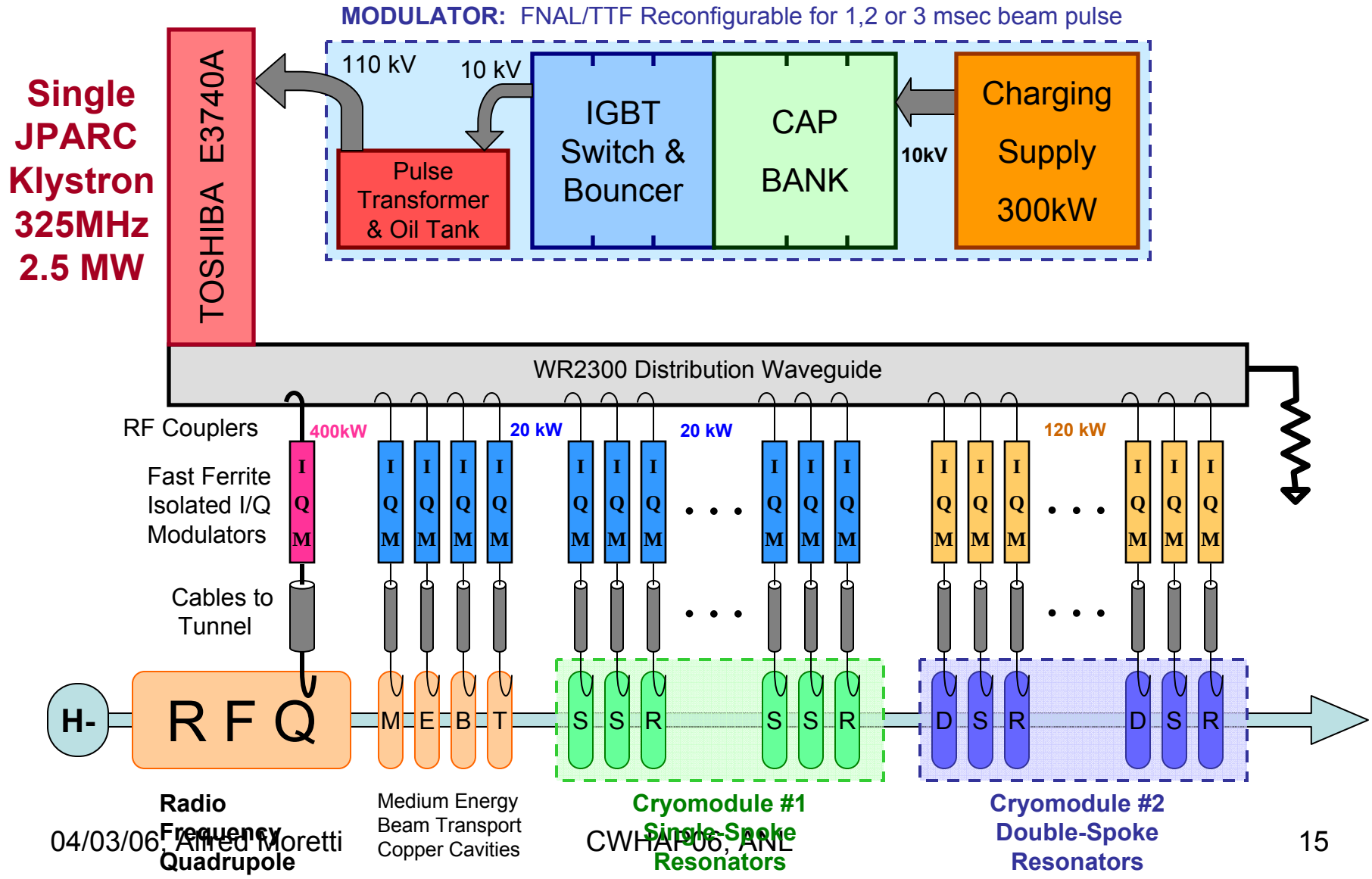


TESLA LINAC 1300 MHz β=1

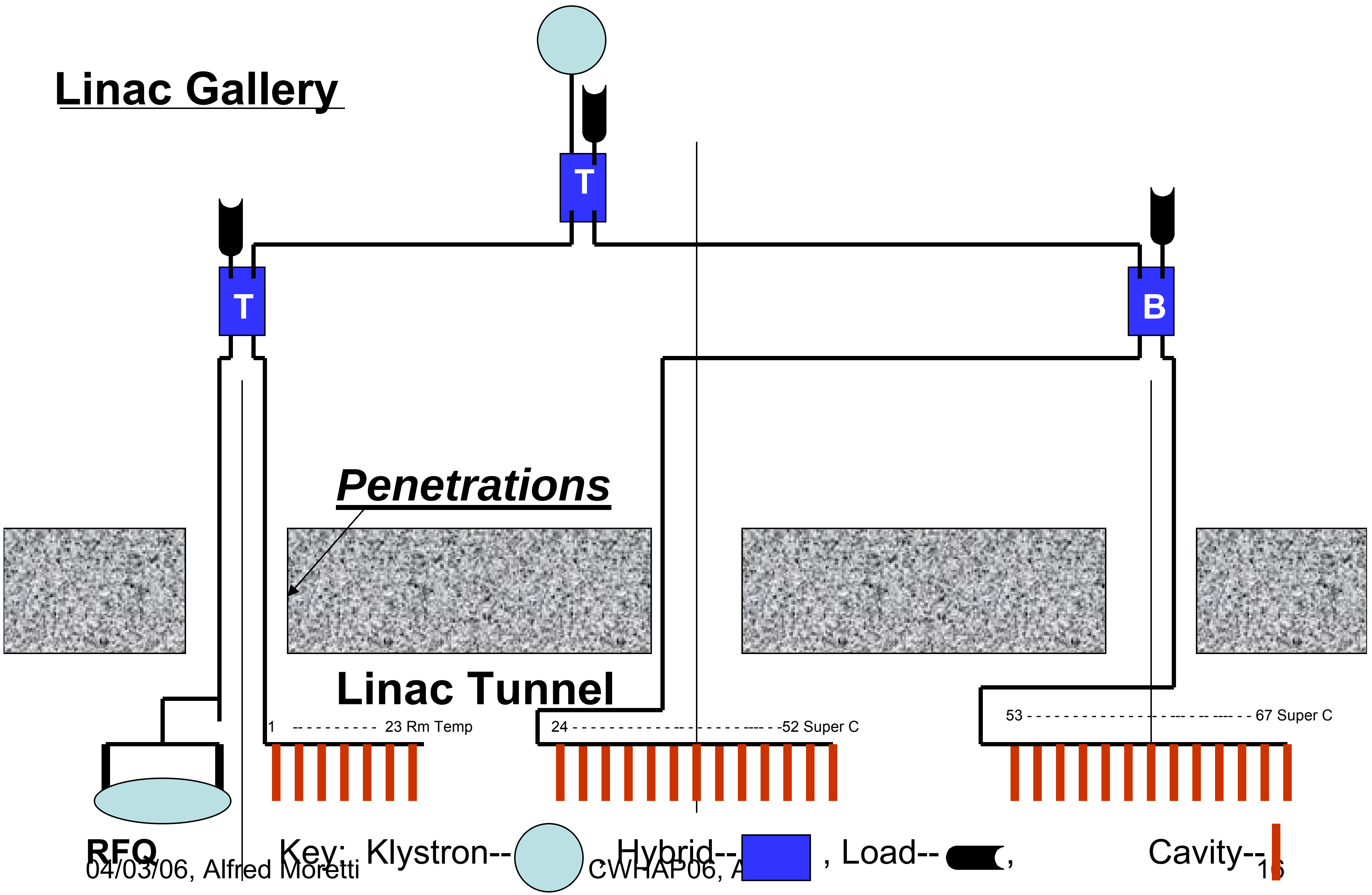
8 Klystrons
288 Cavities in 36 Cryomodules



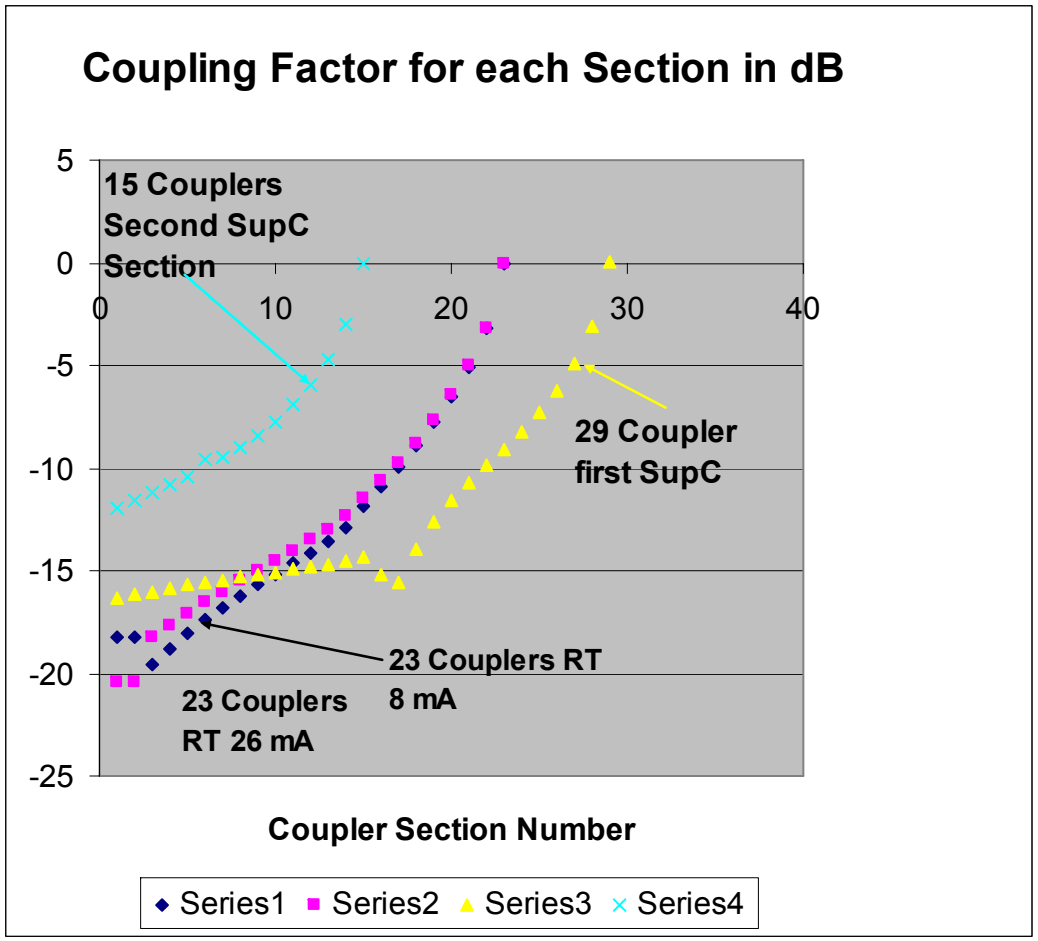
325 MHz RF System



One Klystron Driving 67 Cavities and RFQ



Directional Coupling Factors along the 325 MHz section of the HINS Linac



HINS 325 MHz Klystron

Specifications:

Beam V= 98 kV

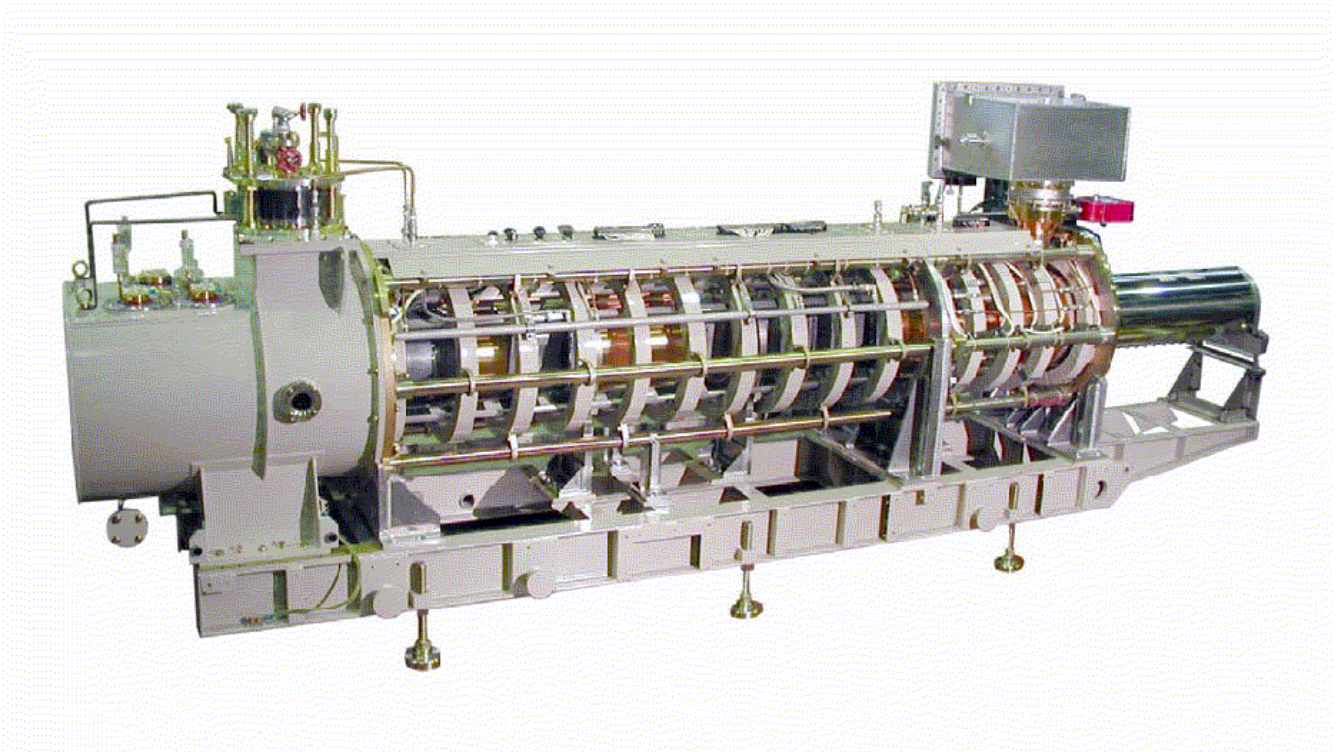
Beam I= 51 A

Perveance=1.75uP

Gain= 47 dB

Efficiency=50 %

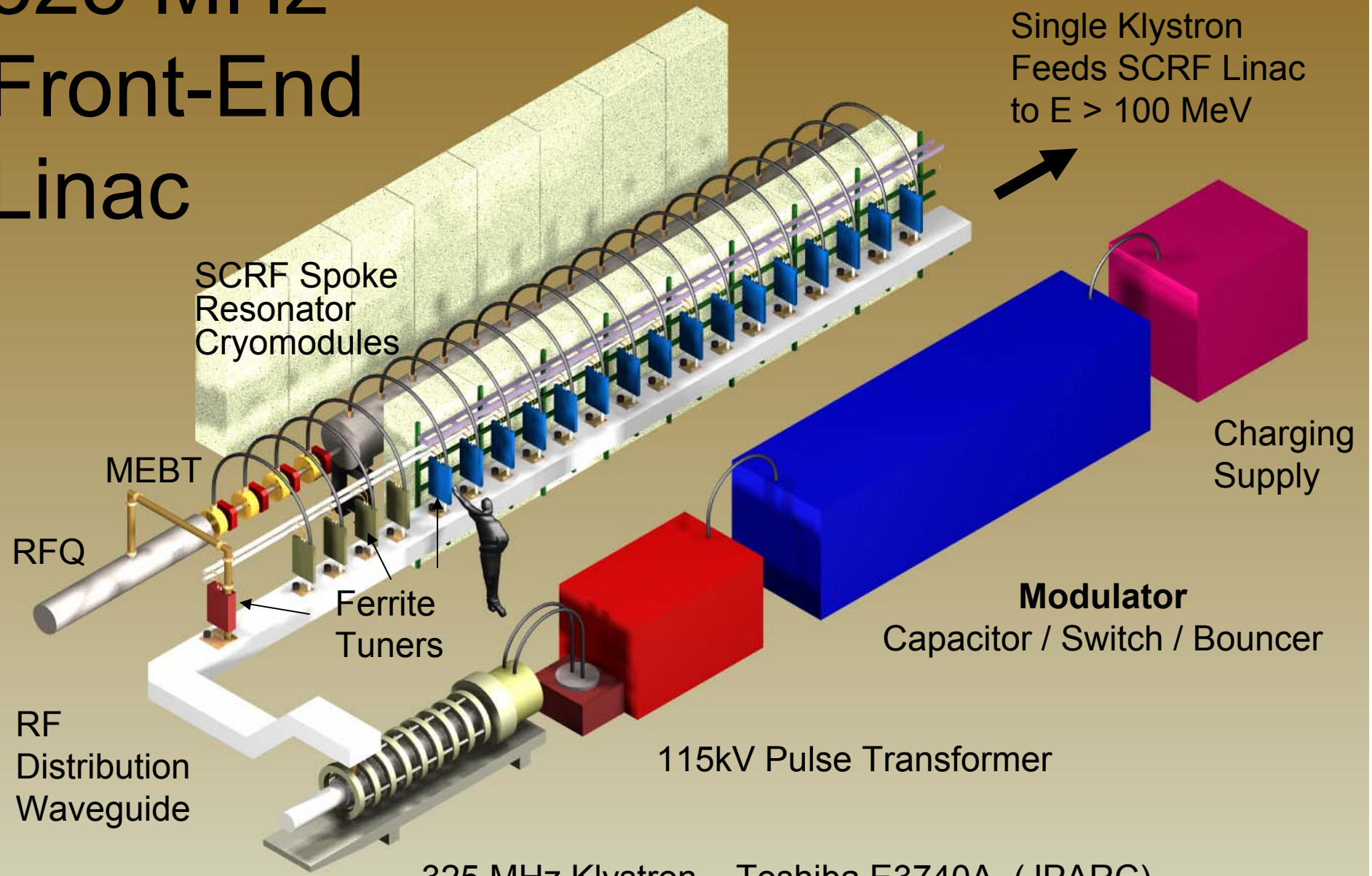
Modulating Anode grounded to make a diode tube.



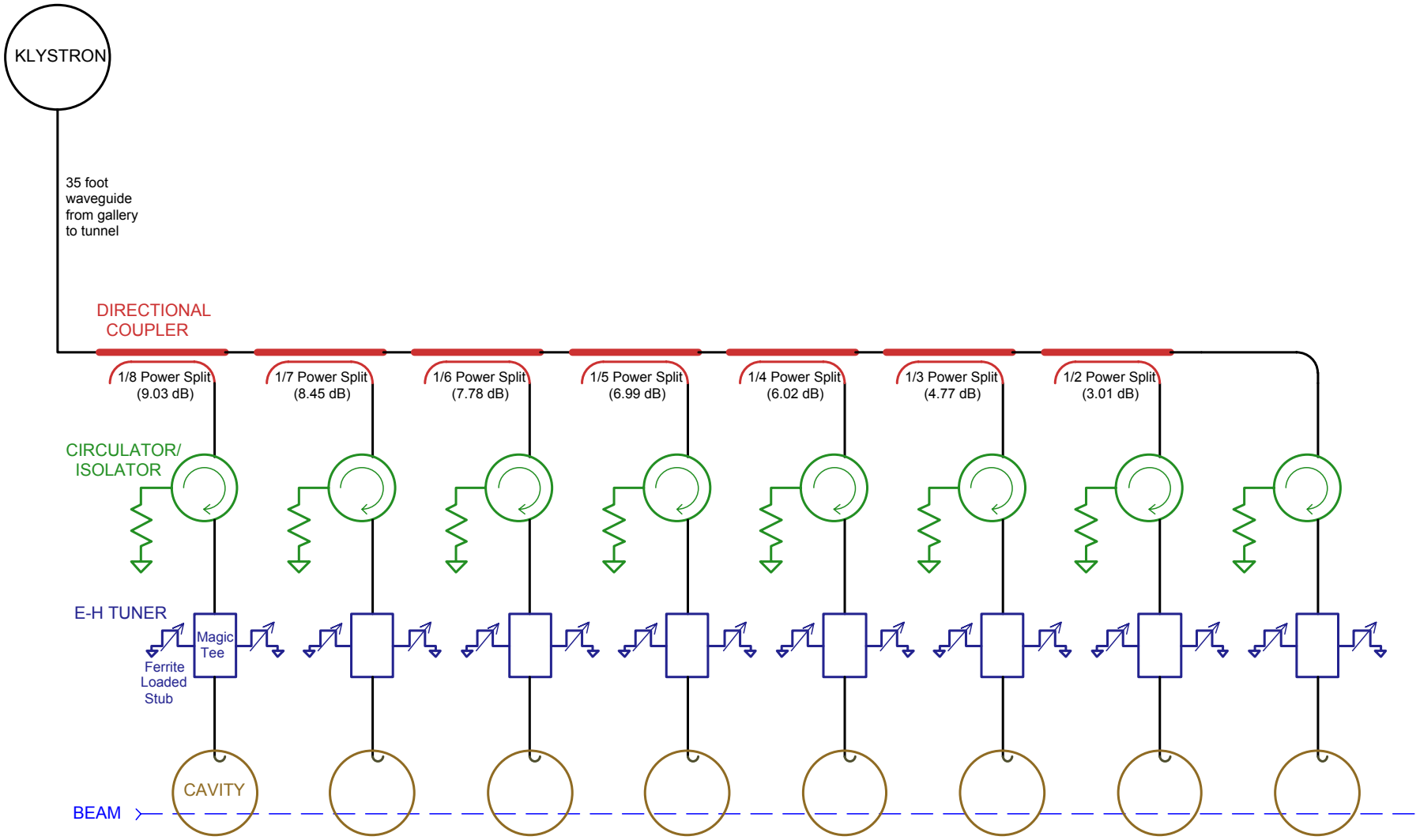
Toshiba E3740AFermi

325 MHz 2.5 MW

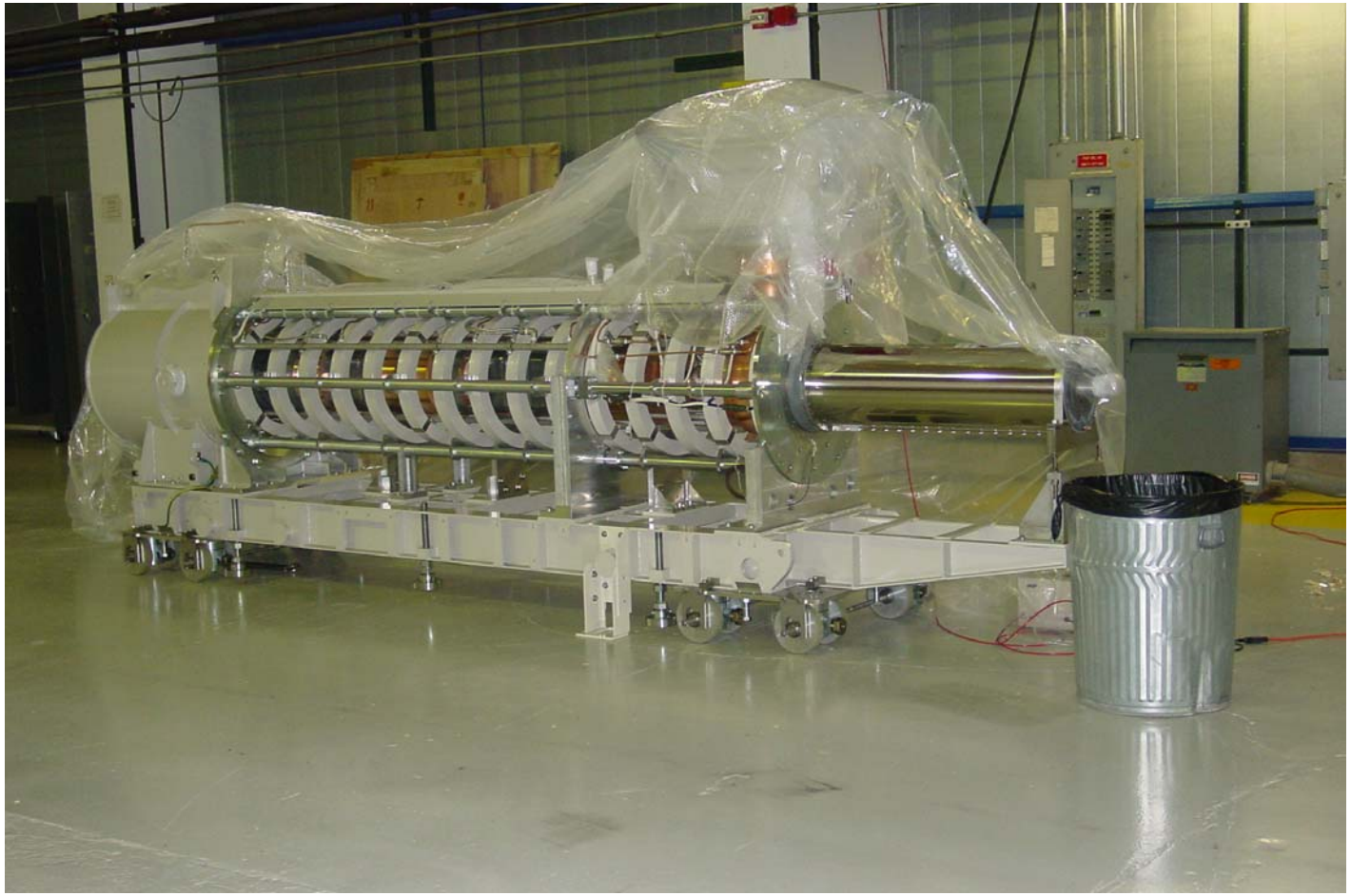
325 MHz Front-End Linac



RF Fan-out for 8 GeV Linac



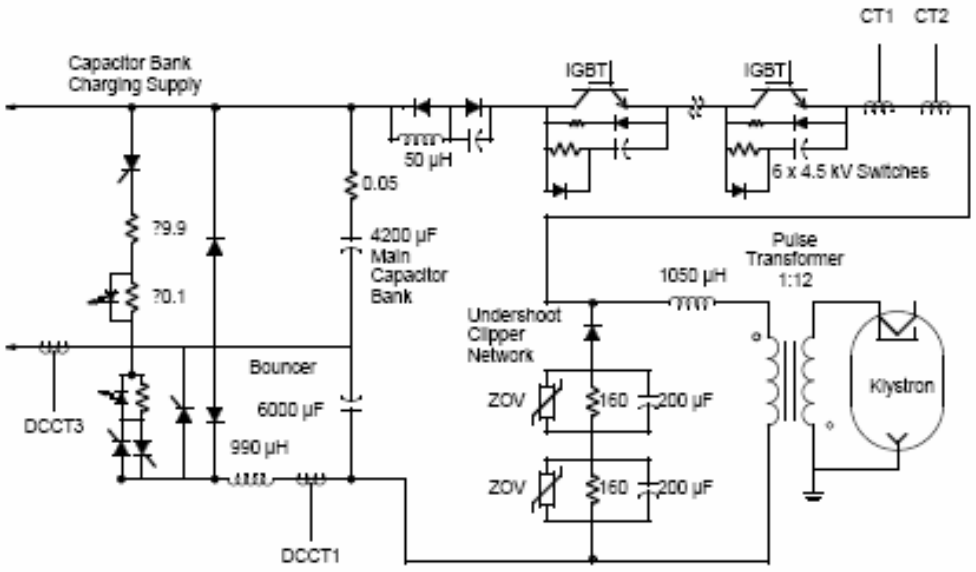
325 MHz kltsron in Meson Building on wheels.



Bouncer Modulator

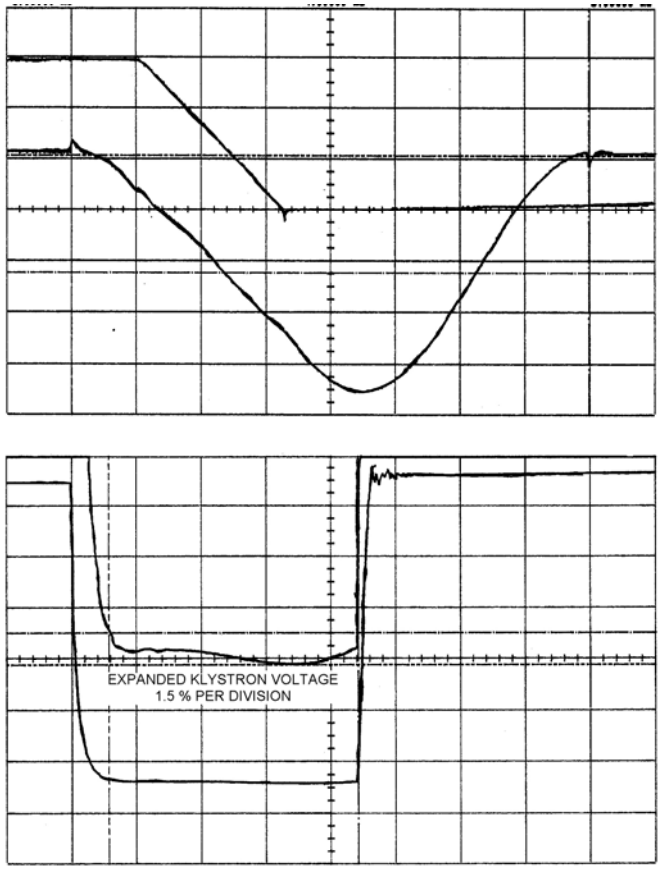
Specifications:

- 9 kV at 1800 A
- Pulses: 1.5 ms at 10 Hz
  3.0 ms at 5 Hz
  4.5 ms at 2.5 Hz
- Regulation: 1 %
- Droop : +/- 0.5 %

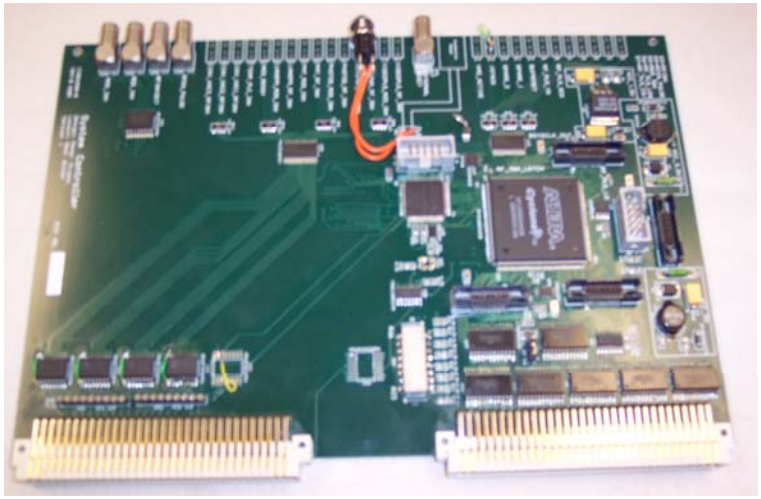


Bouncer Modulator

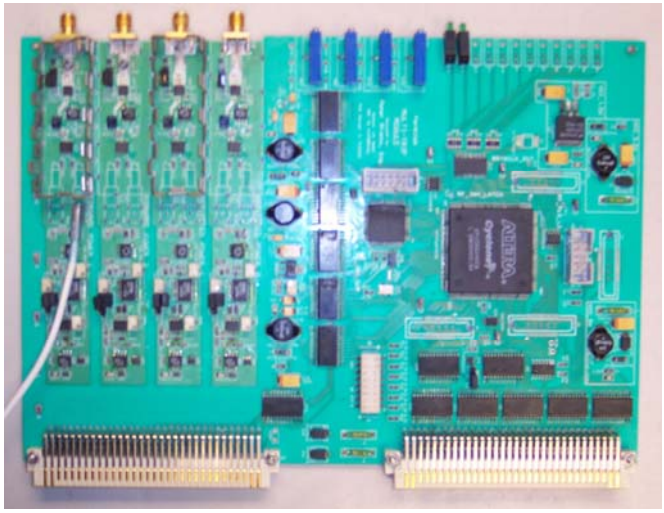
- Switch connects main capacitor bank to transformer during pulse.
- Transformer steps up voltage to 120kV/130A (12:1)
- Main capacitor bank discharges by 20% during pulse
- “Bouncer” circuit compensates for cap bank droop.



Klystron Protection Interlock Boards



System Control



Forward/Reflected Power

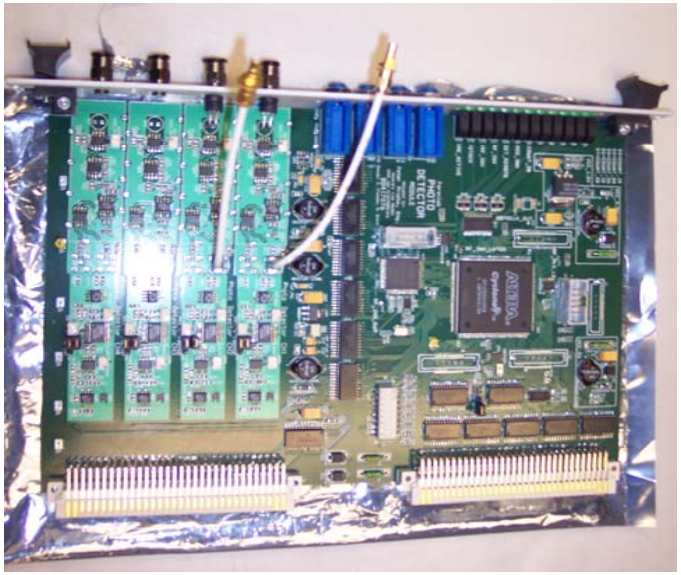
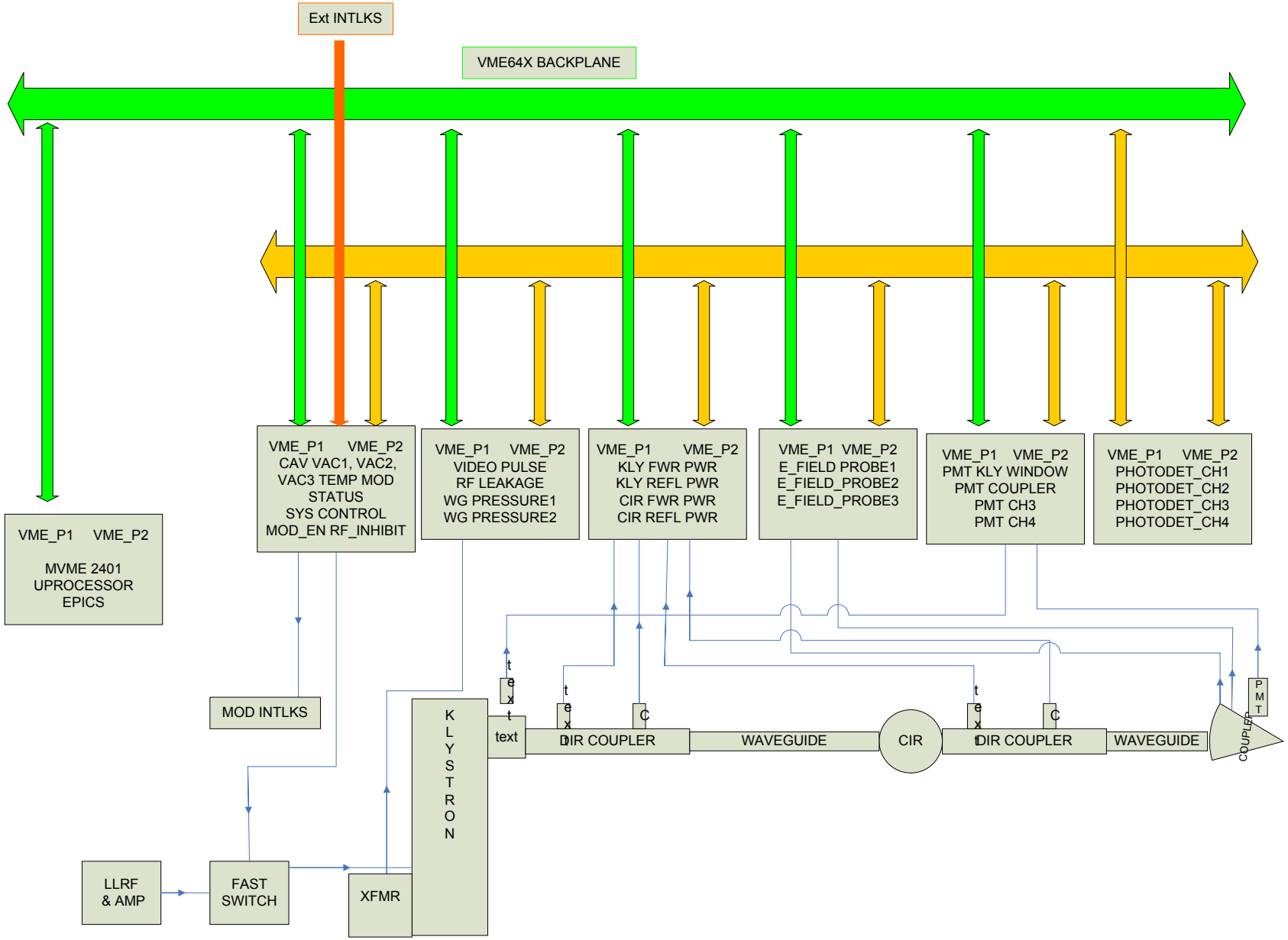


Photo Detector

Video Pulse

HIGH INTENSITY PROTON SOURCE AND SMTF RF INTERLOCKS



AFT 1.3 GHz IQM Specification

IQ-Modulator 1300 MHz, 550kWp

AFT Advanced Ferrite Technology

Central Component: Tunable Phase Shifter

Challenges in Design

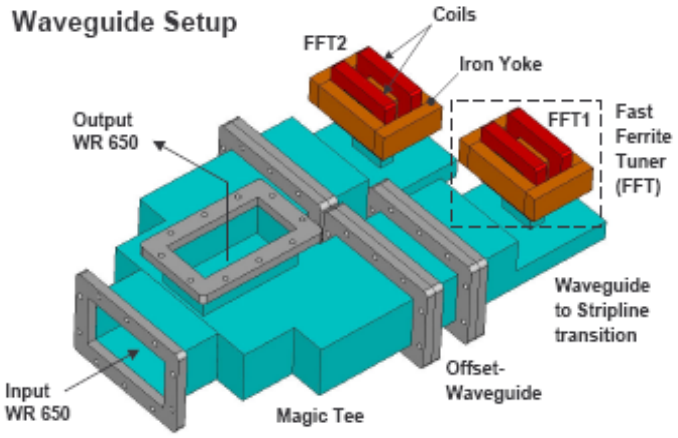
• High RF power → electrical breakdown issues! → water cooling!	550 kW_{peak} 8.25 kW_{avg}
• Low response time, i.e. high tuning frequency → eddy currents handling!	30 µs for 63% of final value
• High delta phase shift	± 90°
• Low insertion loss	< 0.2 dB
• Compact design	

Dr.-Ing. Weil, 24.01.2005 4 zurück weiter beenden

IQ-Modulator 1300 MHz, 550kWp

AFT Advanced Ferrite Technology

Waveguide Setup



Dr.-Ing. Weil, 24.01.2005 6 zurück weiter beenden

Coaxial Ferrite Stub tuners tested at ANL at 352 MHz;

1 5/8 inch line tested to 85 kW peak and o.4 % duty. 120 degree phase shift

3 1/8 inch line tested to 445 kW peak and o.4 % duty. 60 degree phase shift

Conclusions

- **The 805 MHz High Energy Femilab Injector Linac installed in the early 90 ‘s has accomplished its mission of increasing the space charge limit of injecting into the Booster. Early problems with storage life time of the klystrons have been over come.**

- **The 201 MHz section Low Energy section of the Linac being an old machine has problems with tube replacement if the only vendors go out of business. Faster feedback and feed-forwards circuit studies to improve the regulation of Phase and Amplitude due to beam loading are underway.**

- **Most of the components for the 325 MHz HINS linac are on-hand. Testing of the klystron is scheduled for late June or early July of this year.**