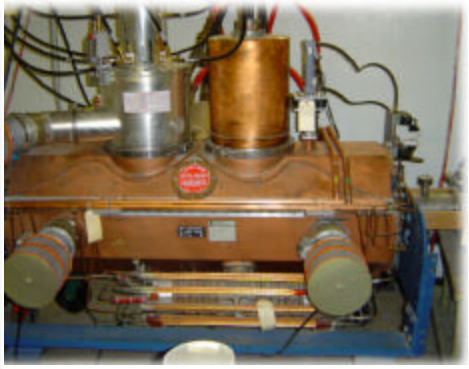
Current Proton Driver Activities in the Accelerator Division

Accelerator Physics and Technology Seminar

Bob Webber

February 2, 2006

In Memoriam



Quentin Kerns

Georg Ohm

$V = i * R$

What is this Proton Driver?

- **8 Gev Superconducting Linac**
  - To provide basis for ILC Test Facility
    - Main Linac Prototype
    - 4-5 GeV Electron source for Damping Ring R&D
  - To serve as high intensity source of protons for Main Injector Neutrino Physics programs

What Makes It Unique?

- **High speed (nsec) beam chopping at 2.5MeV**
- **Spoke resonators and solenoidal focusing in room temperature section**
- **Low transition energy to superconducting accelerating structures (10 MeV)**
- **Superconducting spoke resonator RF structures in low beta sections**
- **ILC cavities and cryostats for beta=1 section**
- **Large number of cavities driven by few high power klystrons**

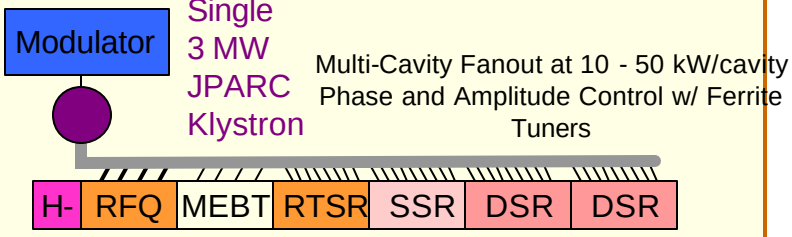
0.5 MW Initial 8 GeV Linac

11 Klystrons (2 types)
449 Cavities
51 Cryomodules

"PULSED RIA"

Front End Linac

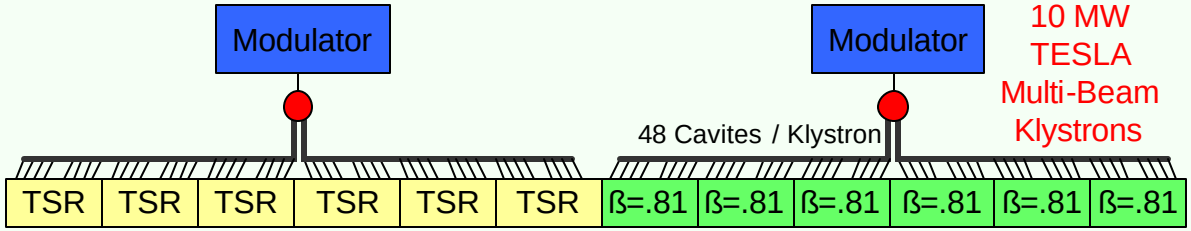
325 MHz
0-110 MeV



ß<1 LINAC

1300 MHz 0.1-1.2 GeV

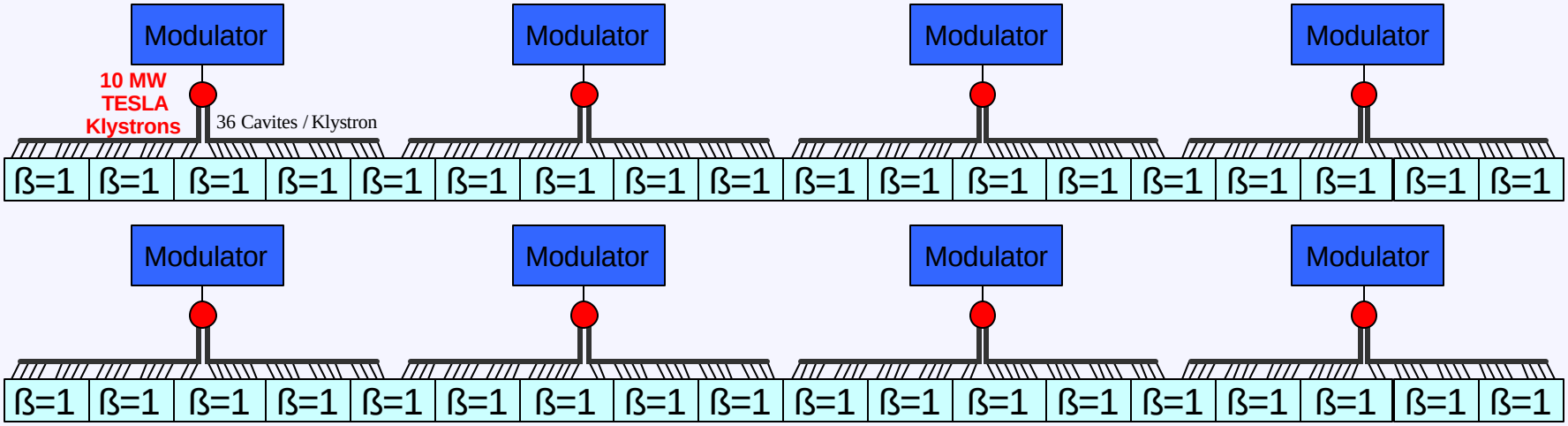
2 Klystrons
42 Triple Spoke Cavities
7 Cryomodules



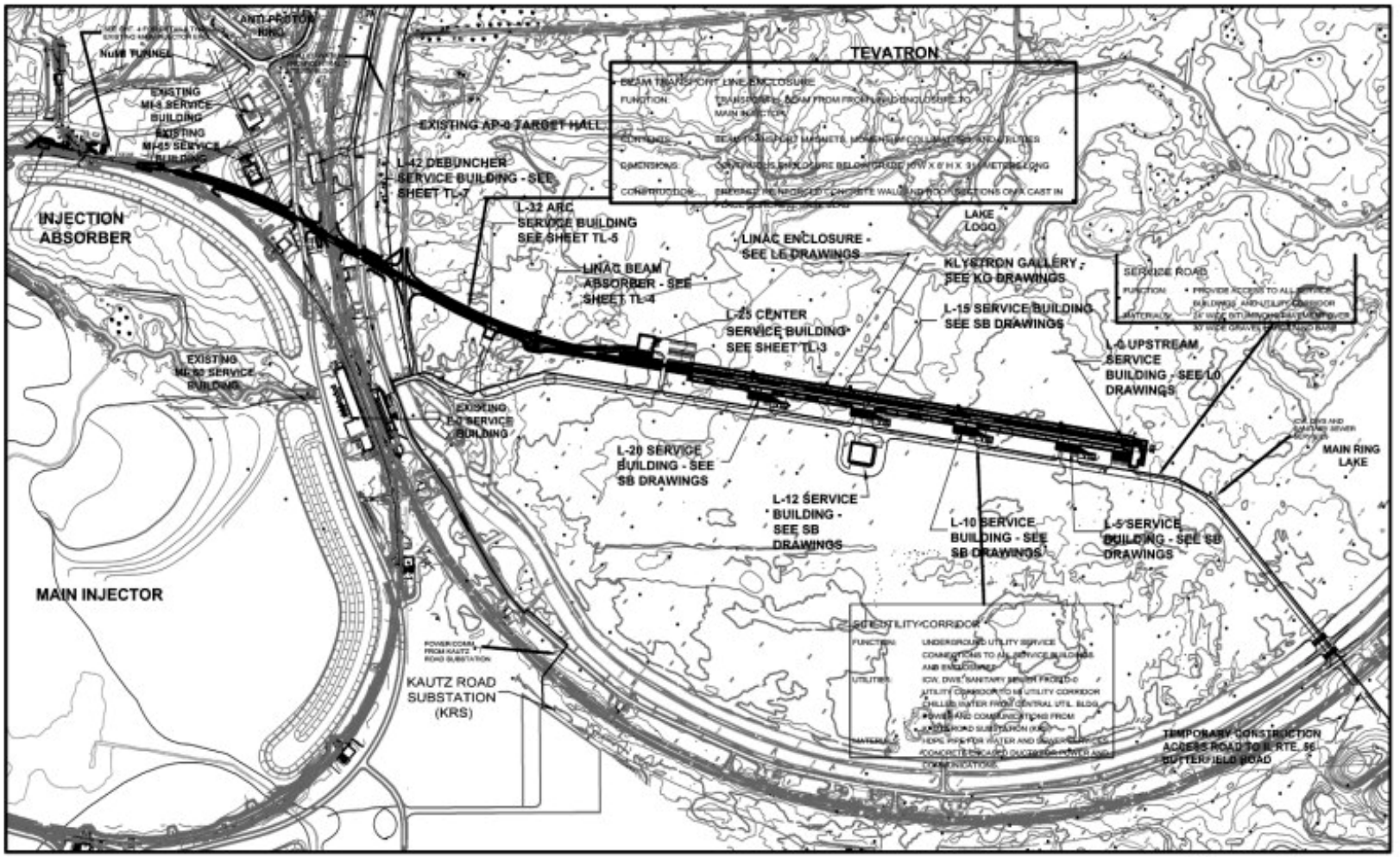
ILC LINAC

1300 MHz ß=1

8 Klystrons
288 Cavities in 36 Cryomodules



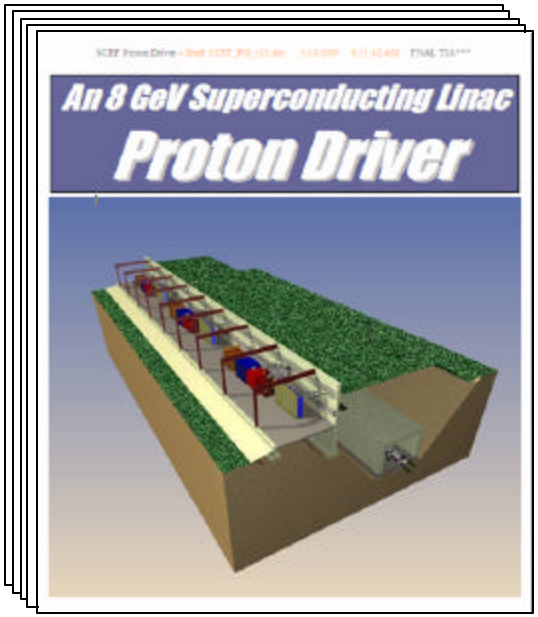
Proton Driver Layout on Site



Proton Driver Information

Project Site:

http://protondriver.fnal.gov



Design Study (Draft, 215 pg.) ➔

http://protondriver.fnal.gov/SCRF_PD_V56.doc

Director's Review:

http://www.fnal.gov/directorate/DirReviews/Dir'sRev_TechnicalReviewoftheProtonDriver_0315.html

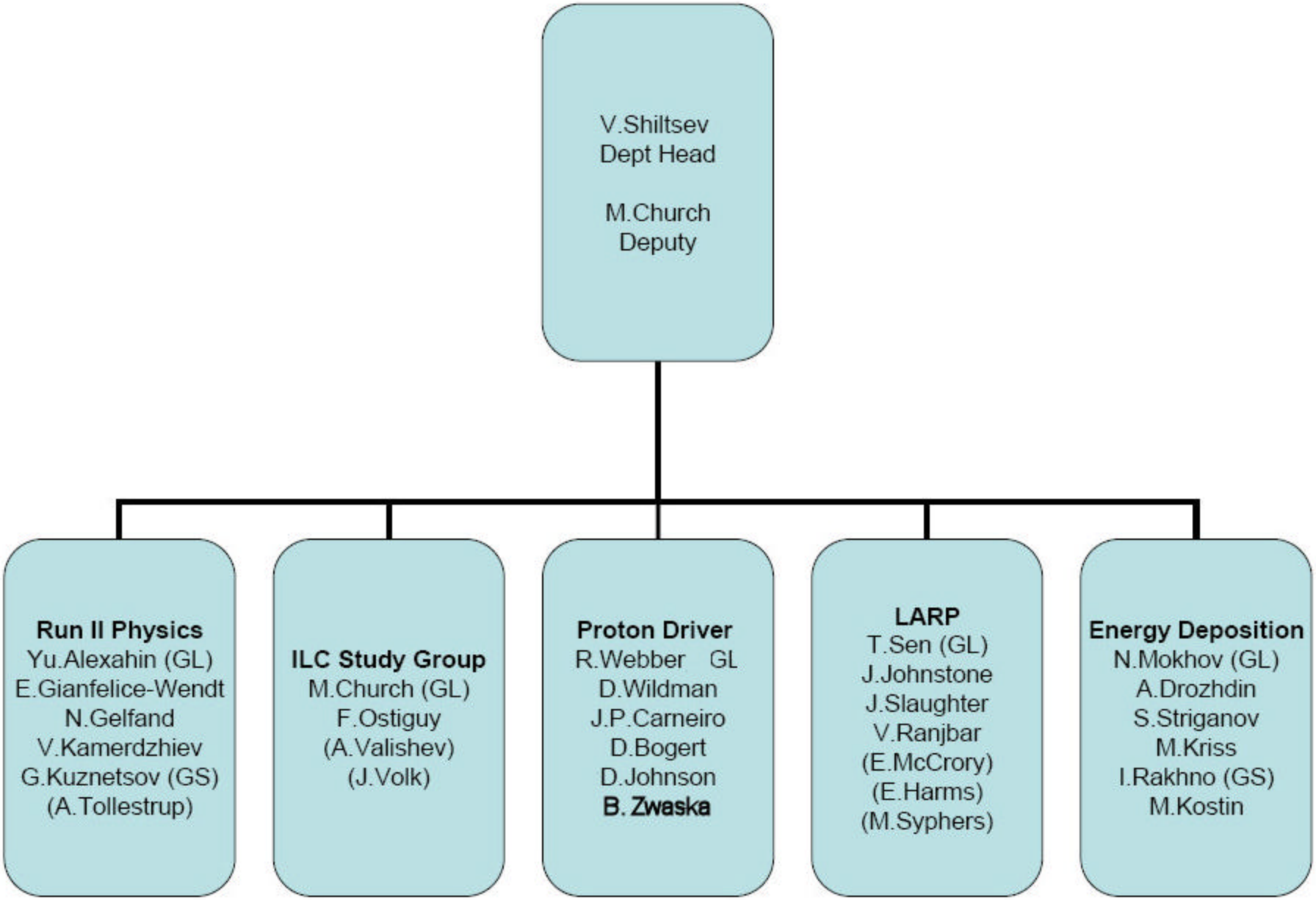
Why Am I Talking About It?

- **Bill Foster convinced Roger Dixon that, as of December 1, I should be replaced as Head of the Instrumentation Department**

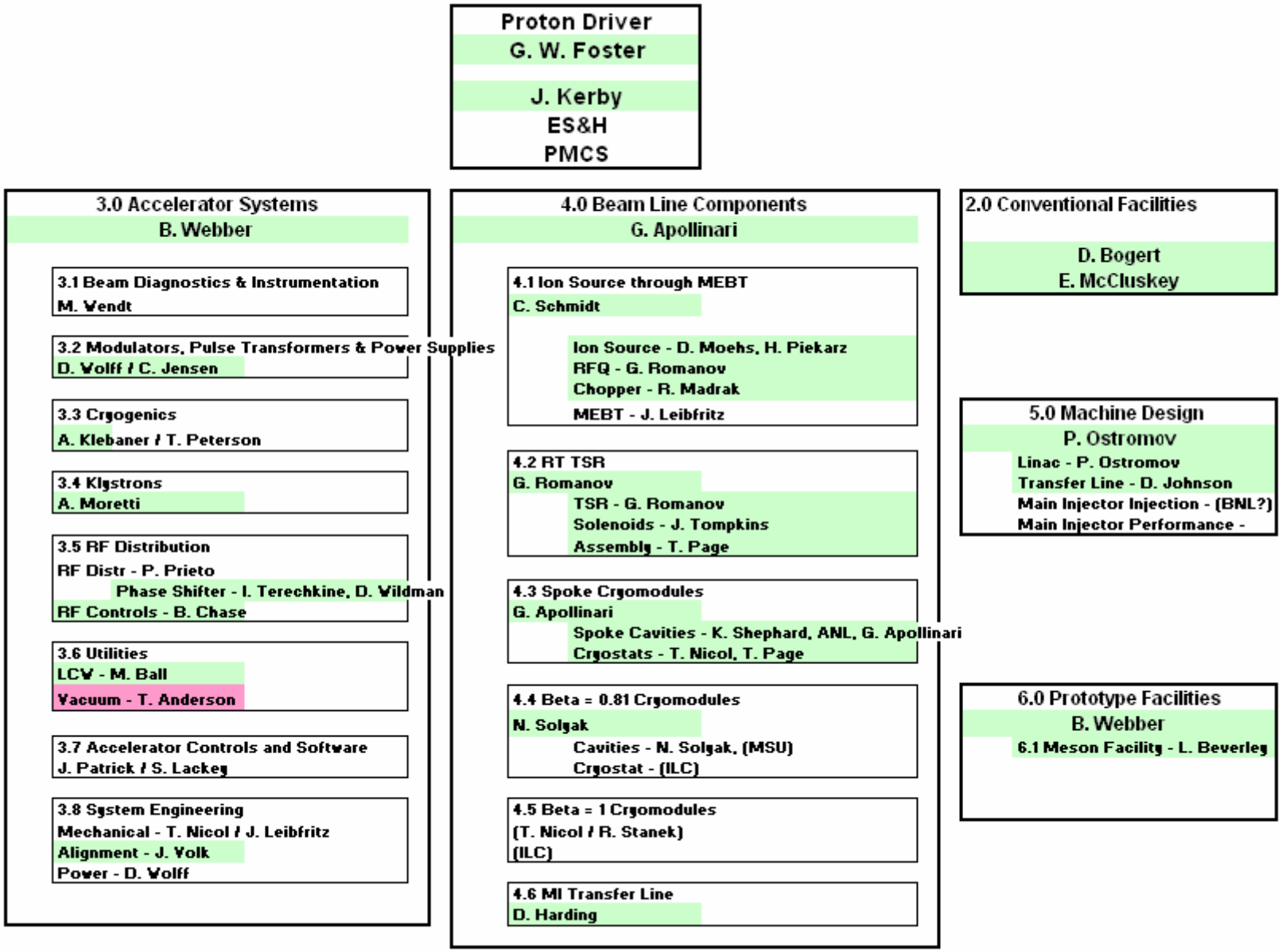
  (I hadn't known that Bill was so concerned about the Instrumentation Department!)

- **I am now assigned to organize and lead Proton Driver efforts within the Accelerator Division**

Accelerator Physics Department

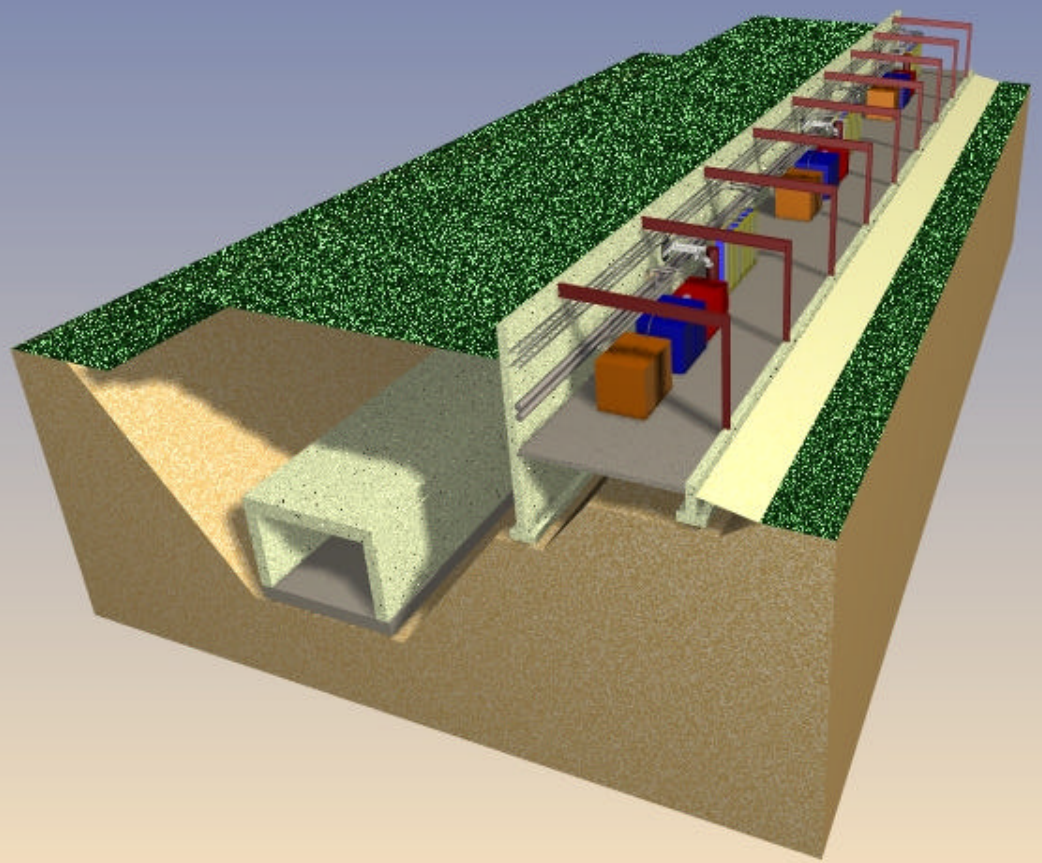


Proton Driver Activity Organization



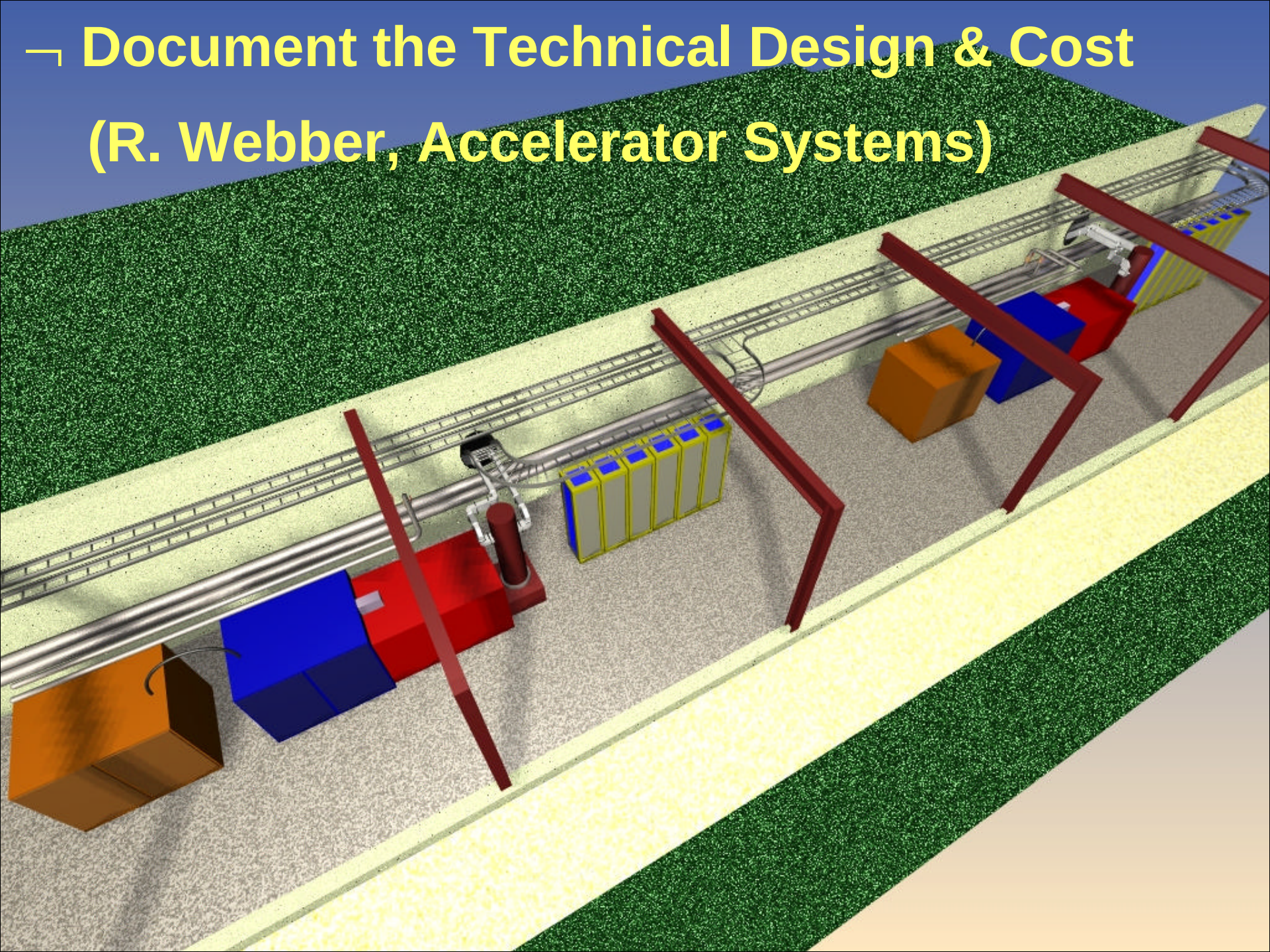
¬ Document the Technical Design & Cost

(J. Kerby, Project Office)



¬ Document the Technical Design & Cost

(R. Webber, Accelerator Systems)



- Document the Technical Design & Cost

(G. Apollinari, Beamline Components

Three Main Foci at this Time

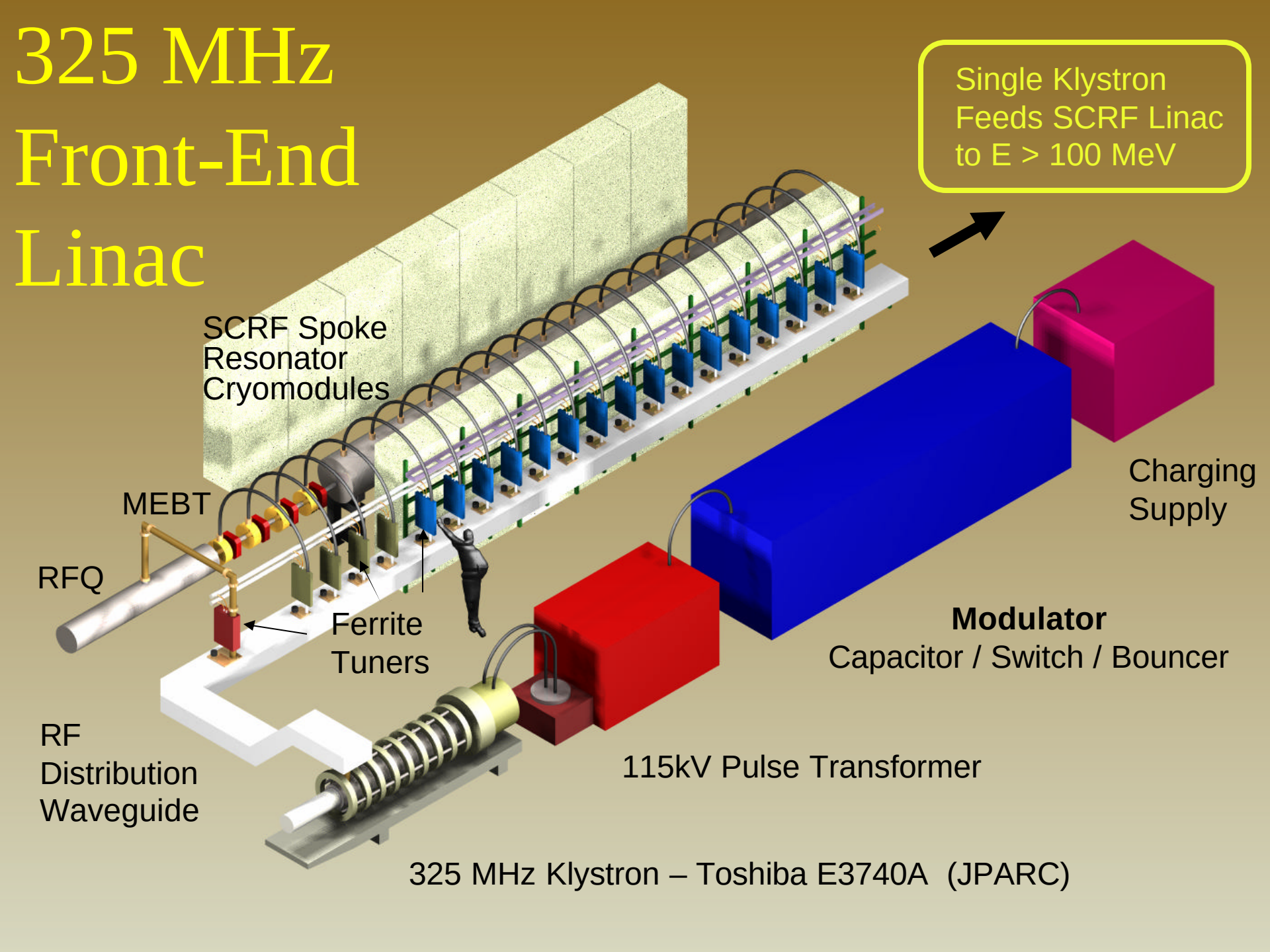
1. **Machine Design and Baseline**
   - Technical Baseline (linac, transport line, injection, acceleration, targetry)
   - Cost Range
2. **Meson Area Front-End Test R&D Program**
   - Beam test of RF Power Split w/Ferrite Vector Modulators
   - First beam through SRF Spoke Resonators
3. **Main Injector at Proton Driver Intensities**
   - Impedance calculations, measurements
   - New MI RF Cavity Prototype (*Inter-Lab Collaboration?*)
   - Beam demonstrations (fast ramping, RR stacking, e-cloud, etc.)
   - Upgrade system designs (momentum collimation, gamma-T, etc.)

- **Remainder of this talk will focus on Accelerator Division activities in support of items 1 and 2**
- **Alberto Marchionni is leading efforts for item 3**

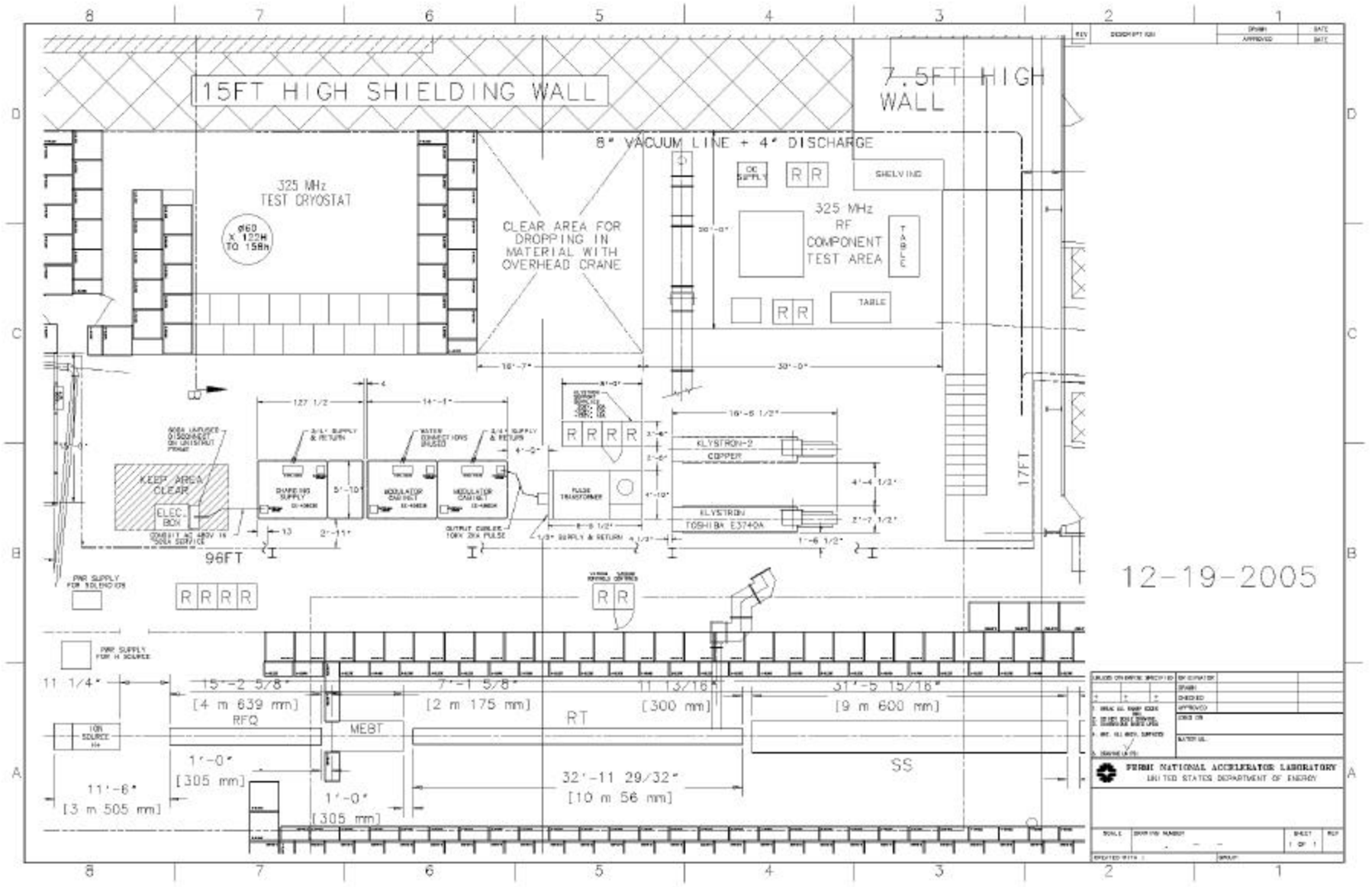
Meson Test Facility Objectives

- **Provide 325 MHz power test facility**
- **Provide 325 MHz superconducting resonator test cryostat**
- **Construct and operate 10 MeV room temperature Linac section**
  - To demonstrate high power RF distribution and vector modulator control of multiple cavities with one klystron
  - To demonstrate performance of solenoidal focusing low energy linac
- **Construct and operate 325 MHz superconducting spoke resonator Linac sections up to ~100 MeV**
  - To demonstrate spoke resonator performance with beam and 3ms beam pulse length

325 MHz Front-End Linac



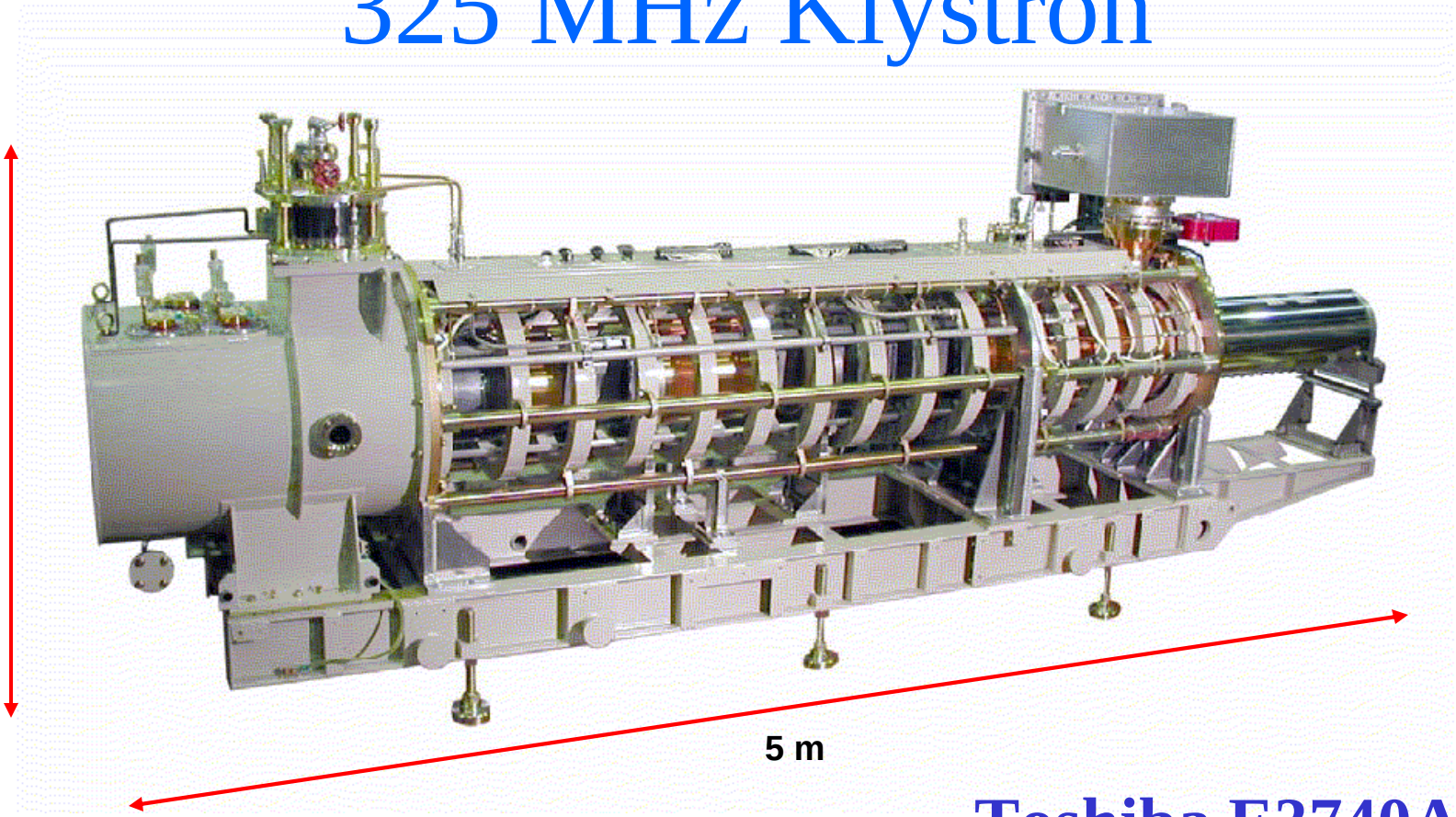
Meson Floor Plan



Cleared Area for Proton Driver in Meson

Pulse Transformer in Meson

325 MHz Klystron



Toshiba E3740A

325 MHz 3 MW

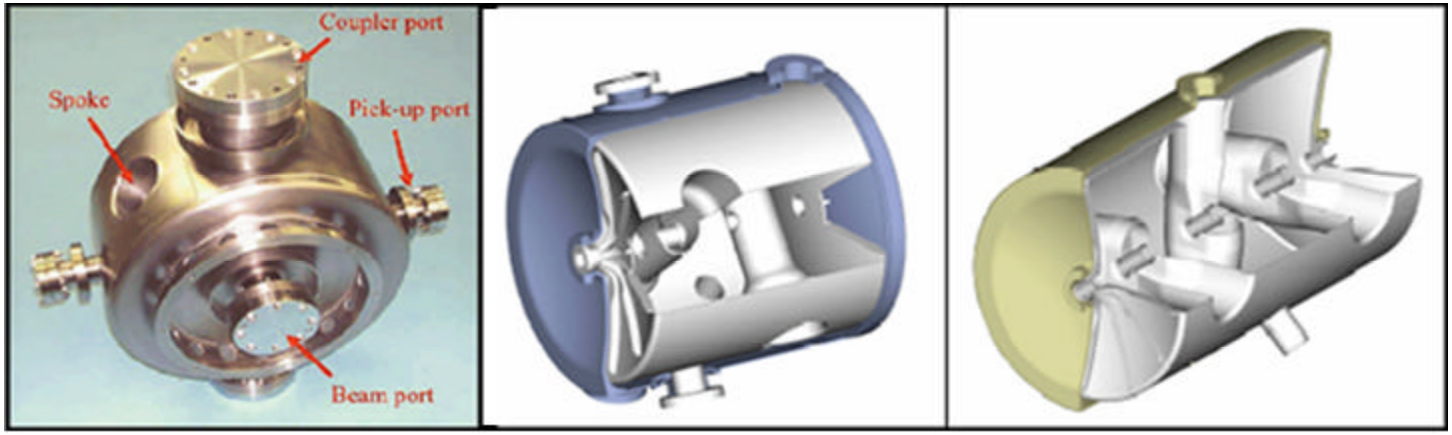
From: Alfred Moretti [mailto:moretti@fnal.gov]
Sent: Tuesday, January 31, 2006 12:18 AM
To: gwf@fnal.gov
Subject: Fwd: Japan visit schedule Jan. 30-Feb. 2

Bill, The tube is great; it was tested to our long pulse length and pulse rates requirements.

RFQ SPEC in Procurement

Operating Frequency	325 MHz at nominal RF power and 27C ambient temp.
Input Energy	50 keV
Output Energy	2.5 MeV
Output Current (max)	40 mA
Pulse Parameters	
Initial operation:	3 msec x 2.5 Hz @ 13 mA (duty factor 0.75%)
Final operation:	1 msec x 10 Hz @ 40 mA (duty factor 1 %)
Input Transverse Emittance	0.24 p mm-mrad RMS Normalized
Output Transverse Emittance	0.26 p mm-mrad RMS Normalized
Output Longitudinal Emittance	Less than 150 p keV deg, rms
Output Twiss parameters	Axisymmetric: $ß_x=ß_y$, $a_x=a_y$ equal within +/-10%
Acceleration Efficiency	> 85% of incoming beam exits at >99% nominal energy
Power Consumption (max)	450 kW(structure) + 100 kW (beam)
Cooling Fluid Input Temp.	32 degrees Celsius
Sparking Rate	$< 10^{-4}$ sparks/pulse
Design Lifetime	20 years
X-Ray Emission	Less than 5 mrem/h

325 MHz SRF Spoke Resonators 10-400 MeV



- **Well Developed Technology for RIA, APT, TRASCO...**
- **Simulations indicate excellent beam dynamics**

  → Never yet tested with beam
- **Runs Pool-Boiling at 4.5K – Simple Cryosystem**
- **R&D Demonstration (SMTF):**

  → beam properties with pulsed operation.

Meson Schedule 2006

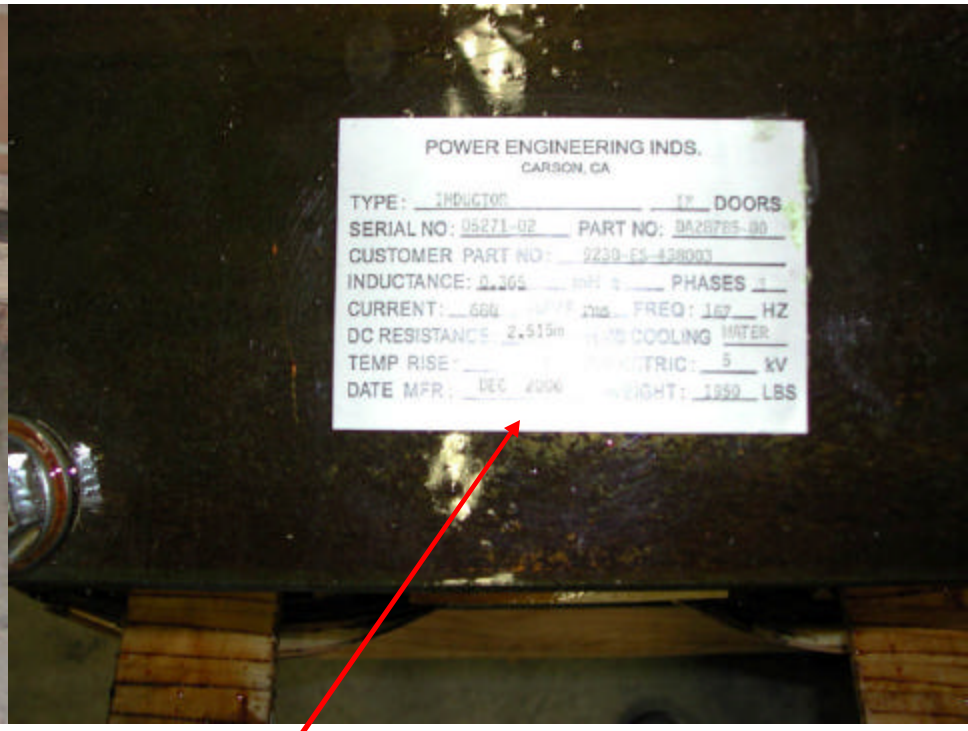
- **325 MHz klystron delivery**
  - March 2006
- **Modulator completion**
  - April 2006
- **325 MHz RF power system commissioning**
  - May 2006
- **325 MHz Test Cryostat (now in final design) delivery**
  - August 2006
- **RFQ (now in procurement) delivery and power testing**
  - October 2006
- **2.5 MeV tests**
  - November 2006
- **325 MHz SC spoke resonator test in test cryostat**
  - November 2006

Klystron Modulator

- **Dan Wolff, Howie Pfeffer, Chris Jensen et al.**

Modulators

Modulator Choke



A modulator ahead of it’s time!

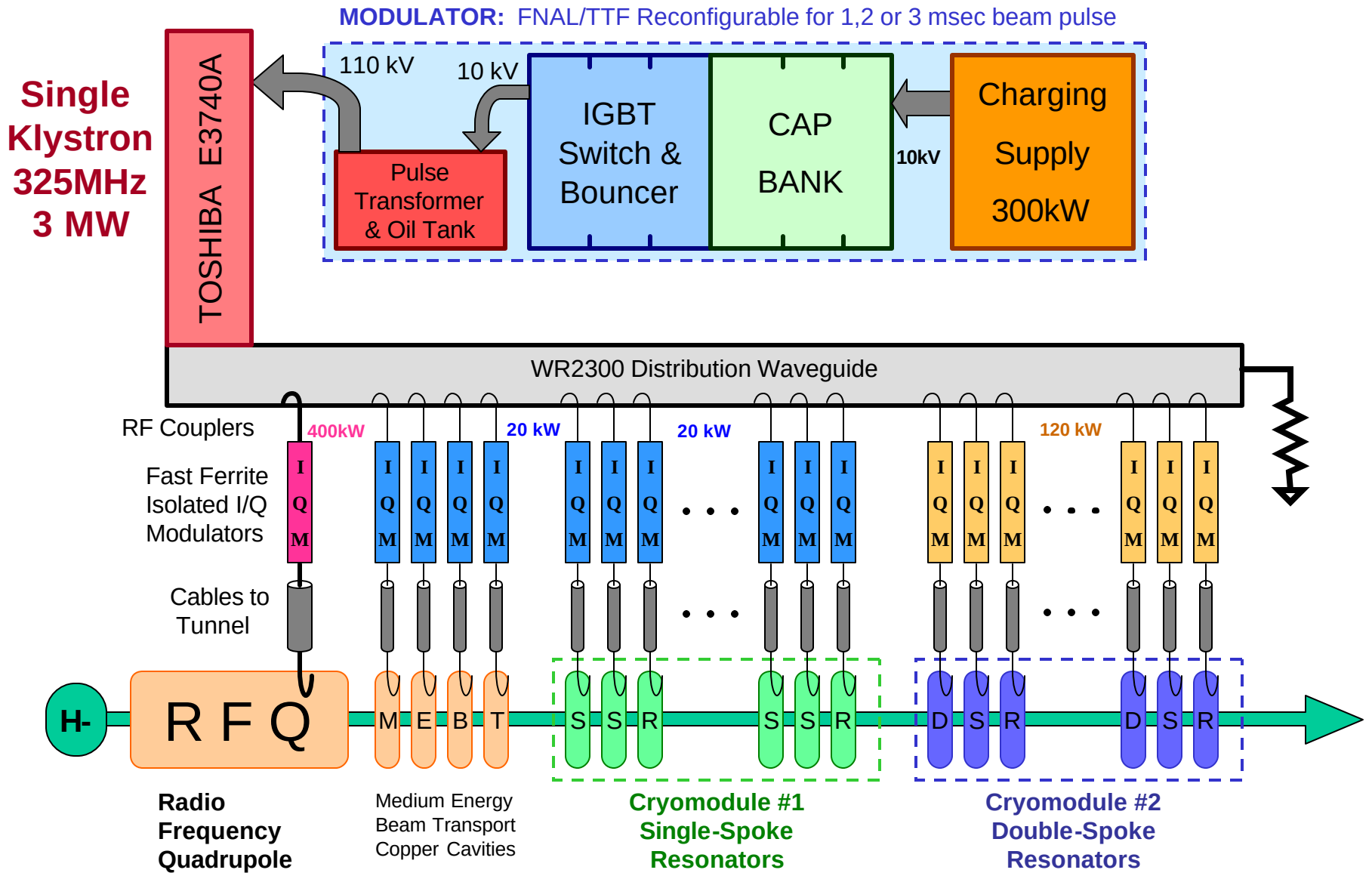
Ferrite Vector Modulator R&D

- **Dave Wildman, Ding Sun, Iouri Terechkine, Steve Hays, Brad Claypool, etc.**

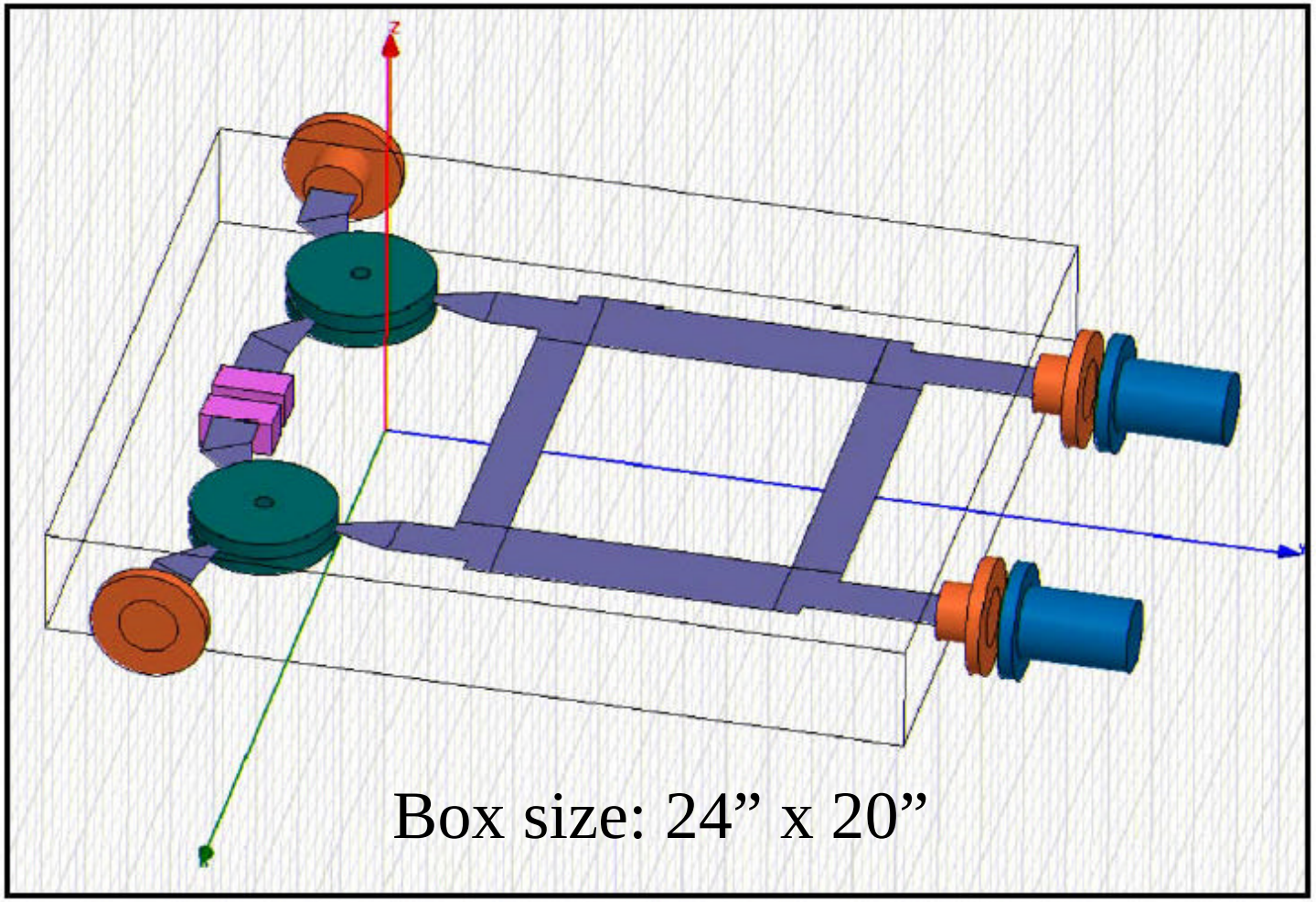
- **Provides fast, flexible drive to individual cavites of a proton linac, when using an ILC style fanout, 1 klystron feeds multiple cavities. Also needed if Linac alternates between e- and P.**
- **Coaxial at 325 MHz, either coaxial or waveguide at 1.3 GHz**

Making this technology work is important to the financial feasibility of the 8 GeV Linac and potentially to ILC.

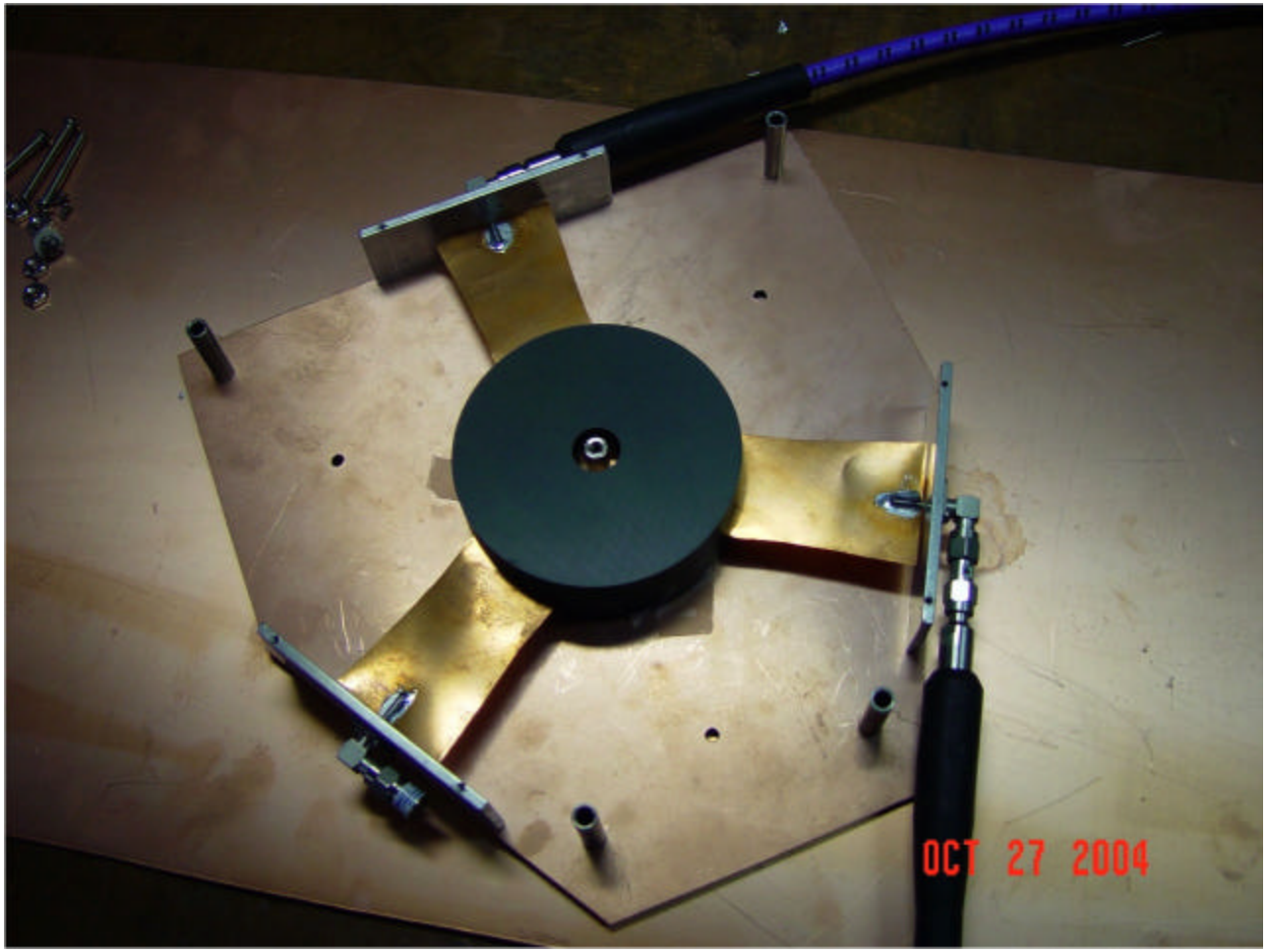
325 MHz RF System



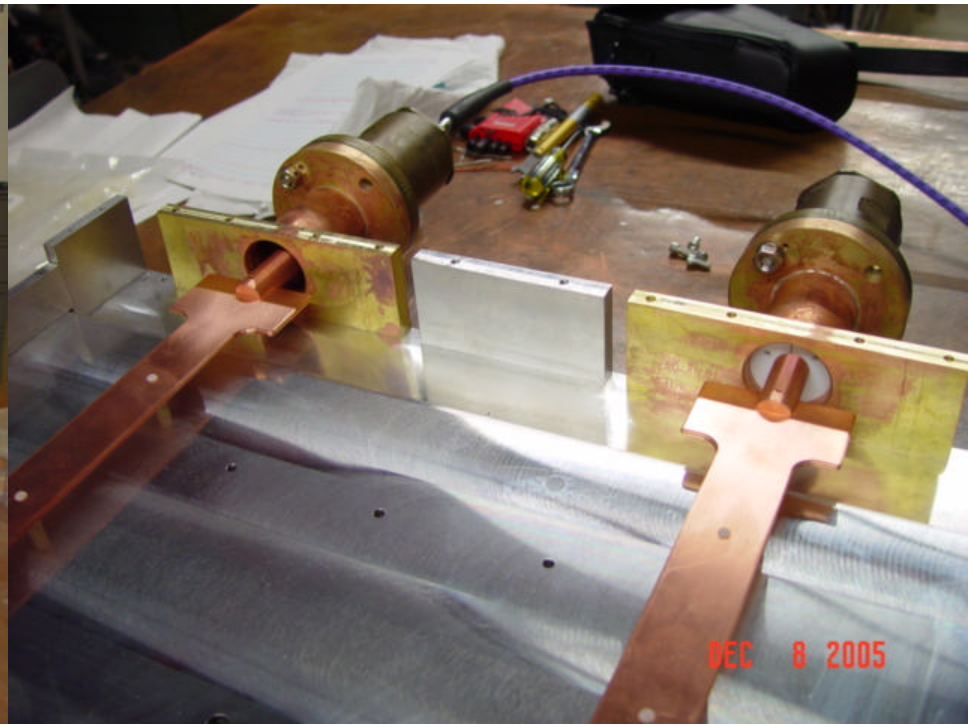
I/Q modulator box (stripline structure)



Prototype Circulator

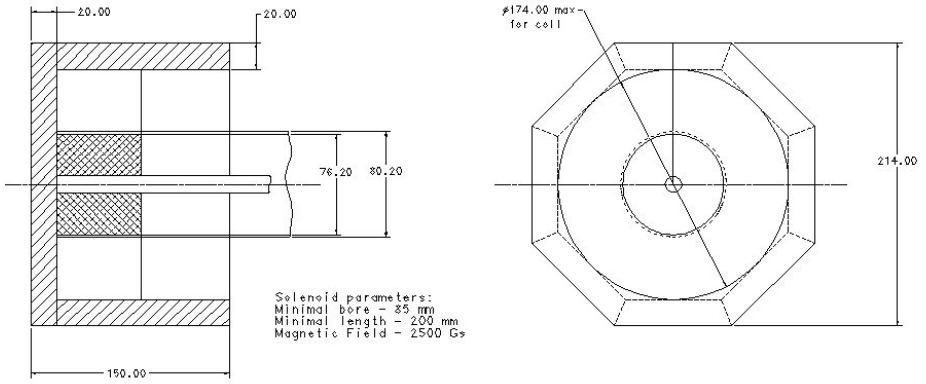


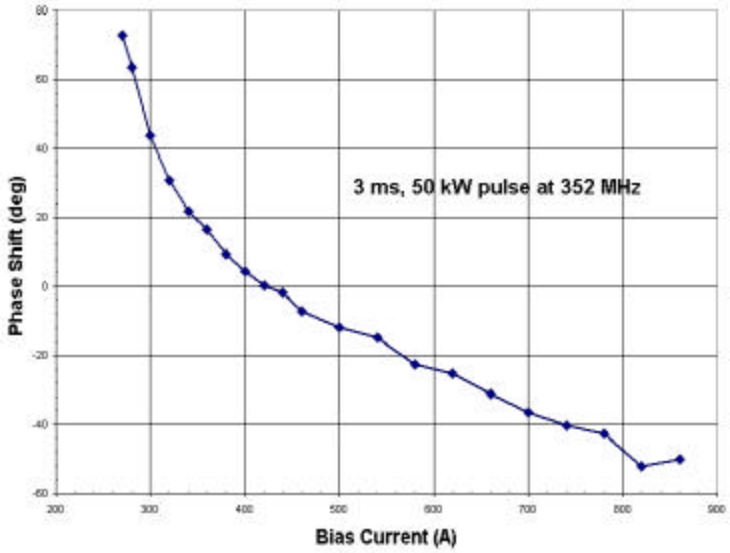
Ding Sun's Hybrid Prototype



Dave Wildman's Coaxial Phase Shifter

- Coax design is preferred at 325MHz
- In-house design tested to 660kW at 1300 MHz
- Tested at 300 kW at Argonne with APS 352MHz Klystron
- Fast coil and flux return should respond in ~50us



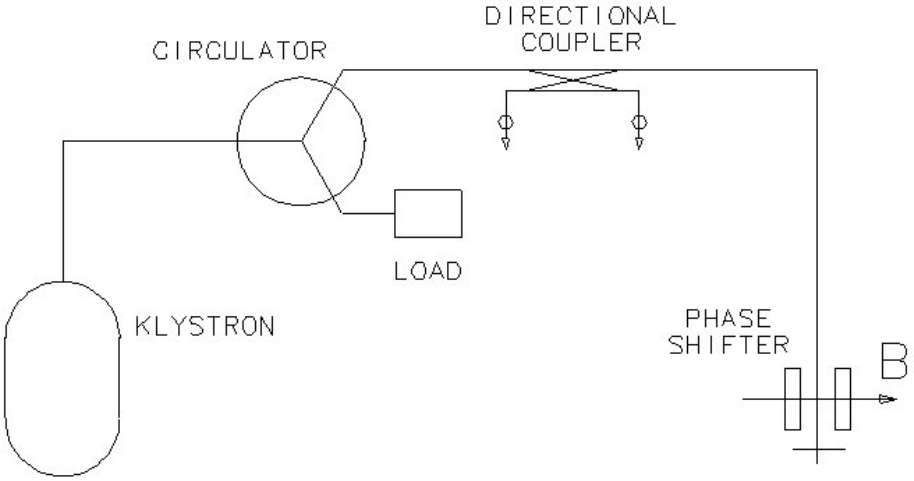


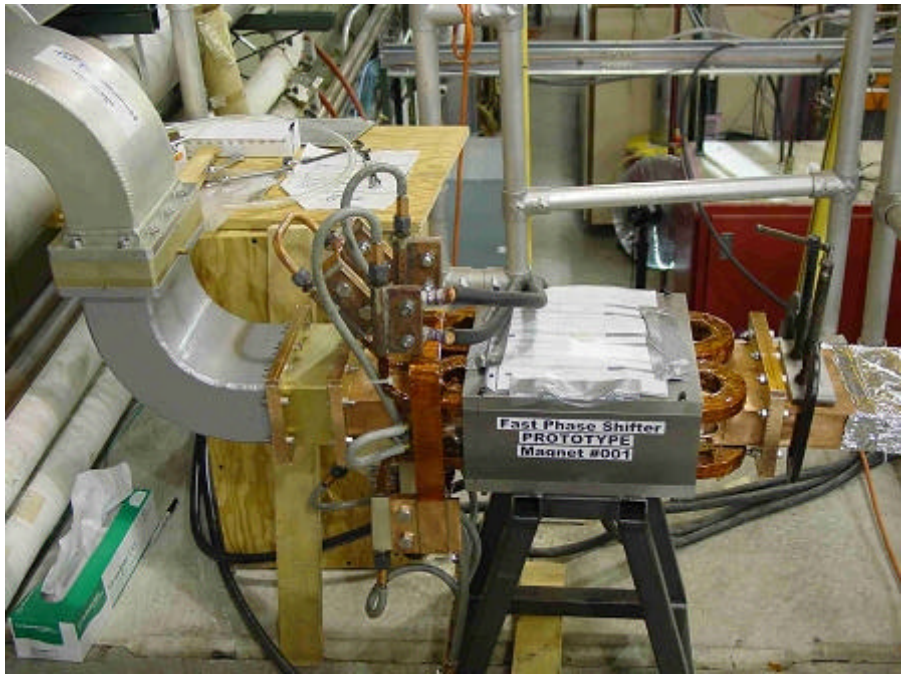
High Power Ferrite Modulator Test at FNAL

1300 MHz Klystron

T = 250 µsec

F = 5 Hz





Existing A0 Klystron was used for testing

Waveguide Version

HPVM Driver

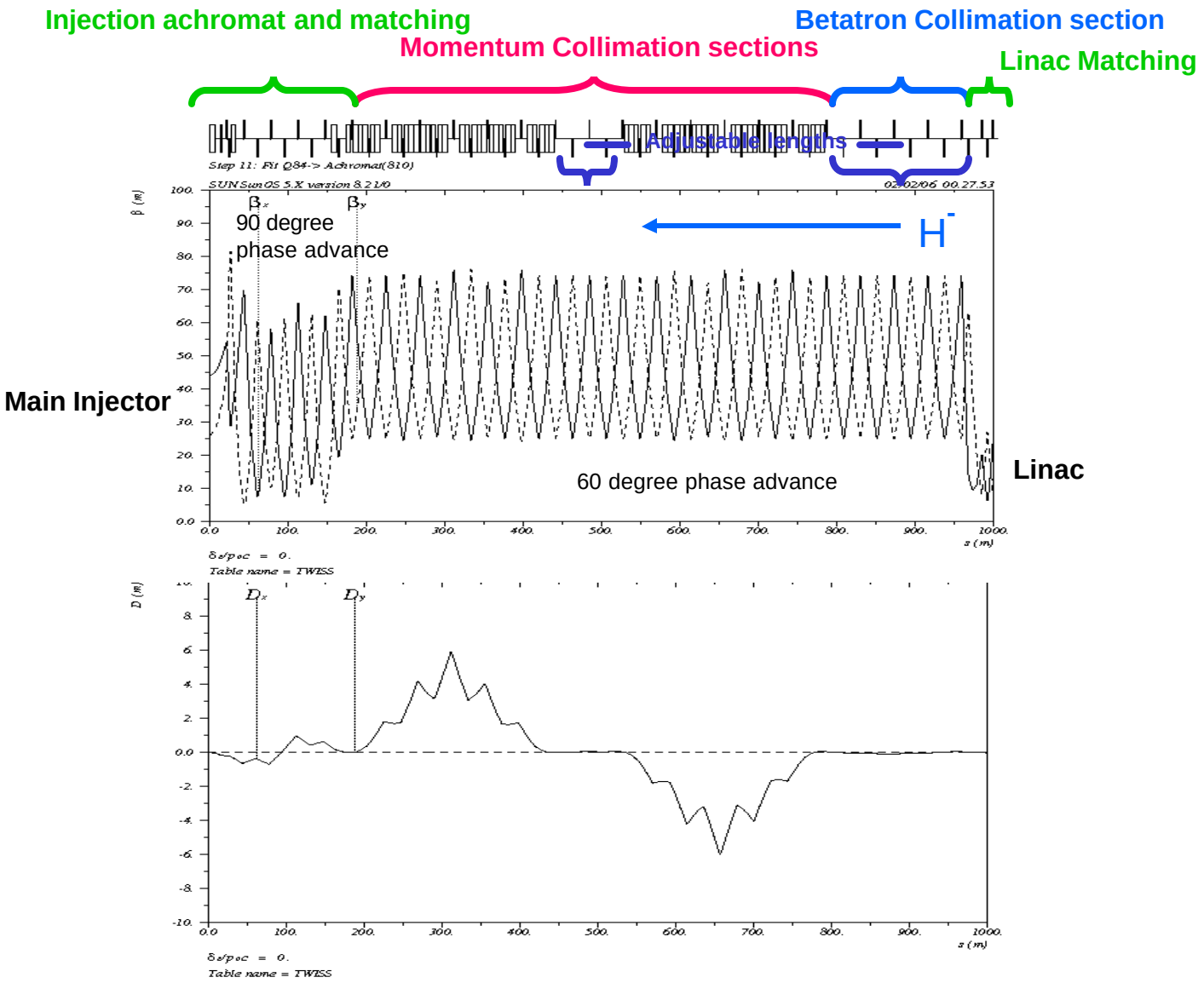
Transfer Line and MI Injection Design

- **Dave Johnson and Dixon Bogert**
  - Following work by others for previous Proton Driver efforts

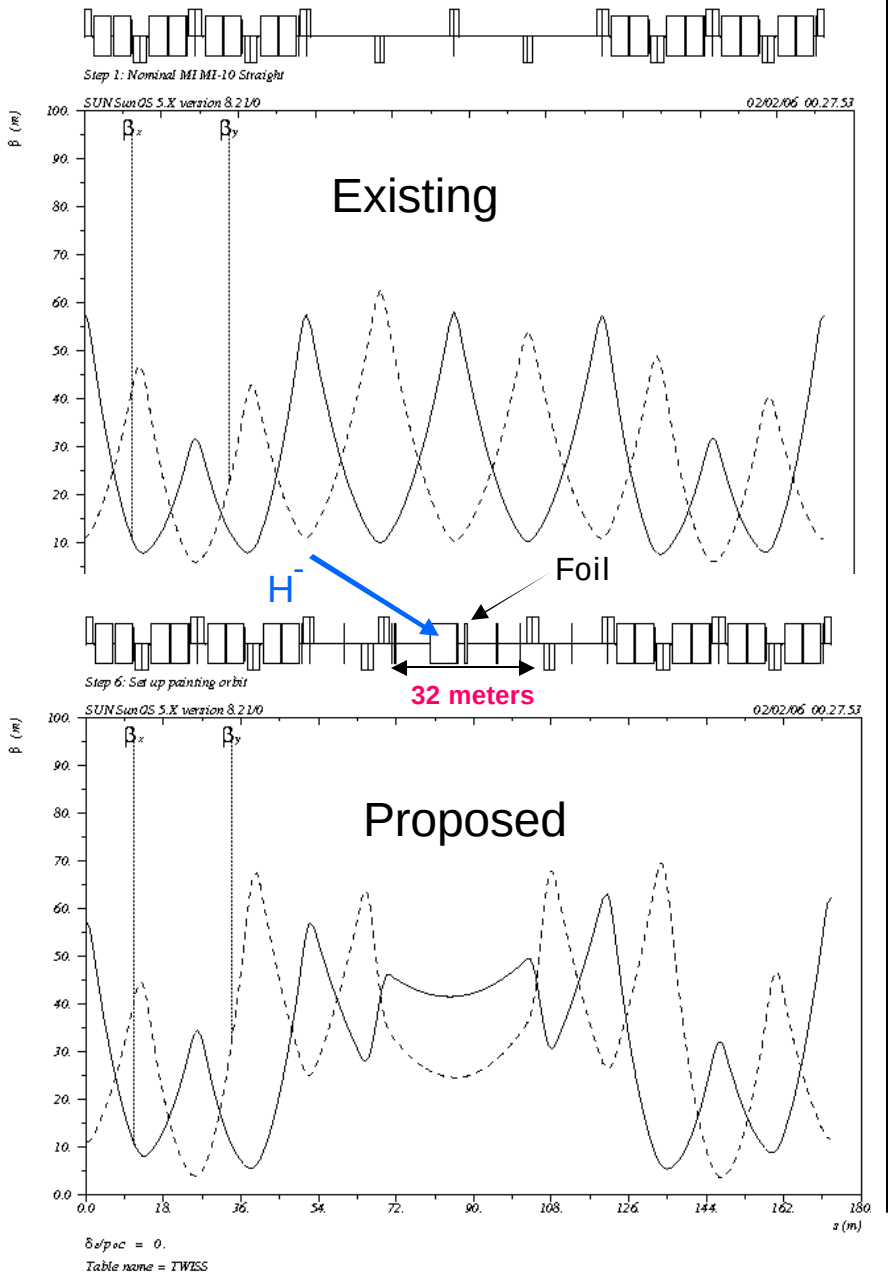
H- transport line and Main Injector injection

- **Refinement and Optimization of work by A. Drozhdin, W. Chou, and others on the H^- transport line and Main Injector injection which includes:**
  - Inclusion of most recent information from b=1 Linac design.
  - Creation of independent achromats for +/- momentum collimation
  - Creation of injection achromat and matching section
  - Investigation of MI-10 injection insertion modifications
  - Optimization of site coordinates to minimize impact of construction on MI tunnel (cost and schedule impact)
- **Baseline layout and design will include H- stripping by foil, but will not preclude a future upgrade for laser stripping**
- **Design will include options for PD beam to MiniBoone and injection into Recycler.**
- **Continued refinement of requirements and specifications for transport line collimators and injection absorber**
- **Design will build upon experiences of SNS**
- **Establish collaboration with experts at FNAL, BNL, and SNS**

Revised H- Transport Line



Revised Main Injector MI10 Injection straight

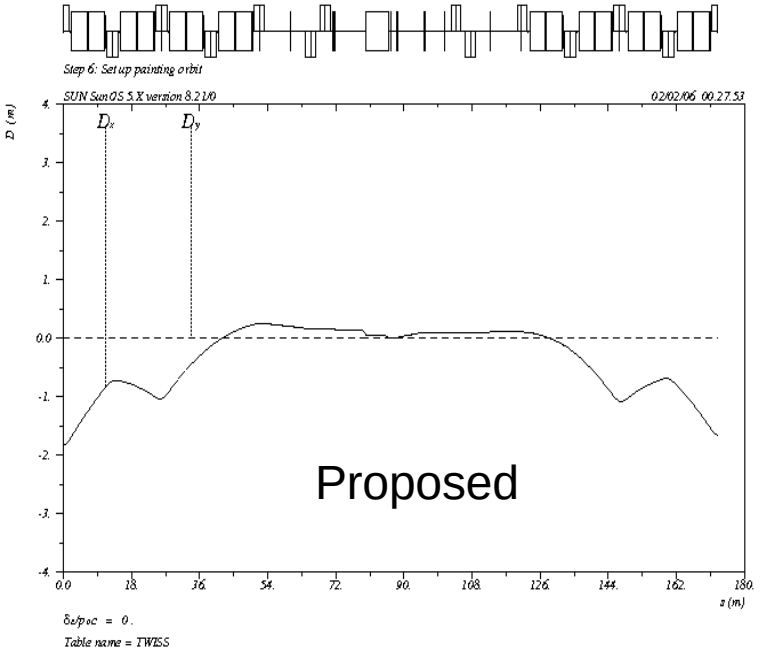


Advantages:

- Increases available space for injection devices
- Flexible injection optics
- Allows greater separation between circulating beam and foil after injection
- Removal of Quad from middle of injection devices

Disadvantages:

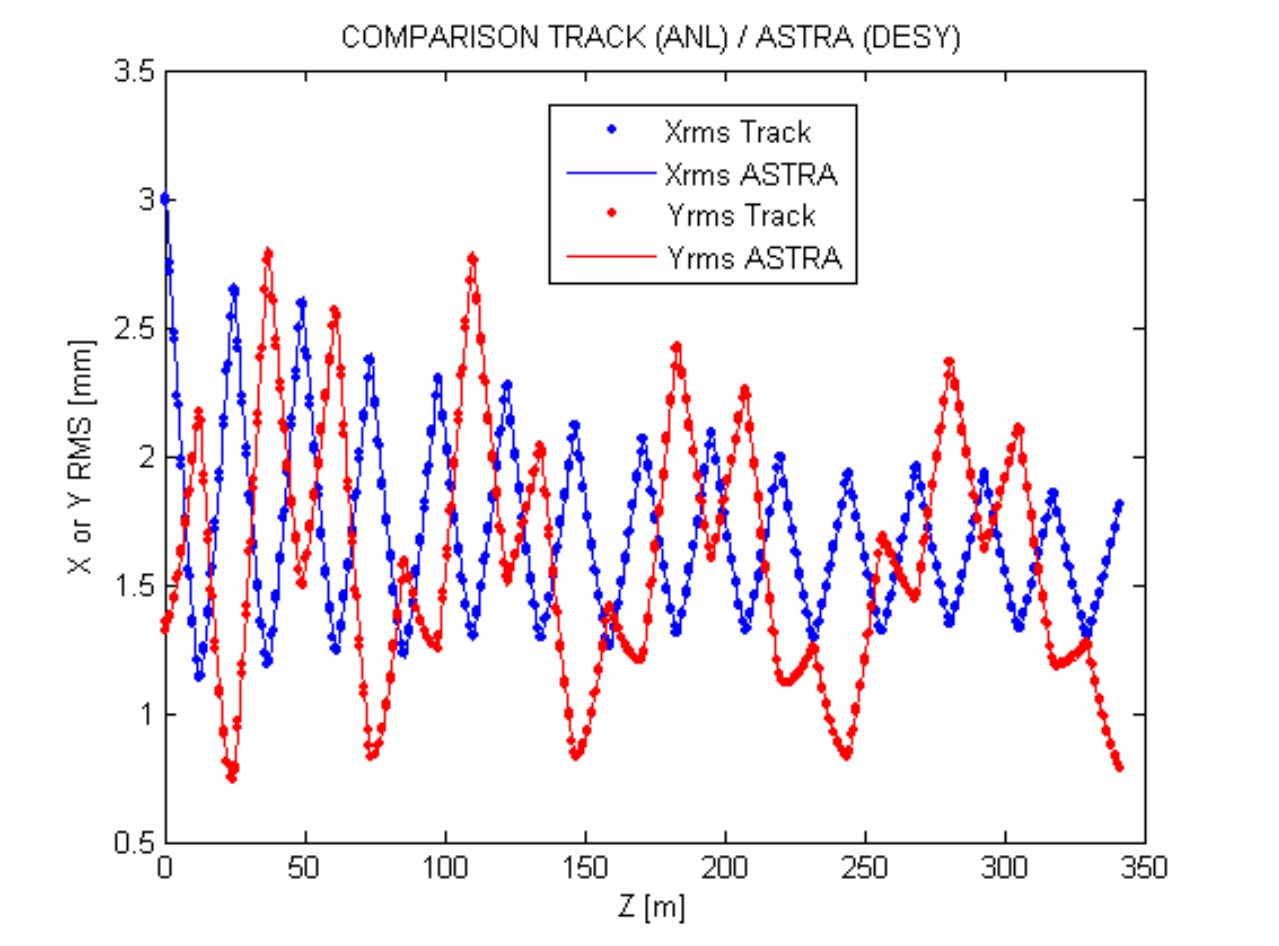
- Requires additional quad circuits for matching into MI
- Must keep vertical beta below 70 m in dipole section



Linac Simulations

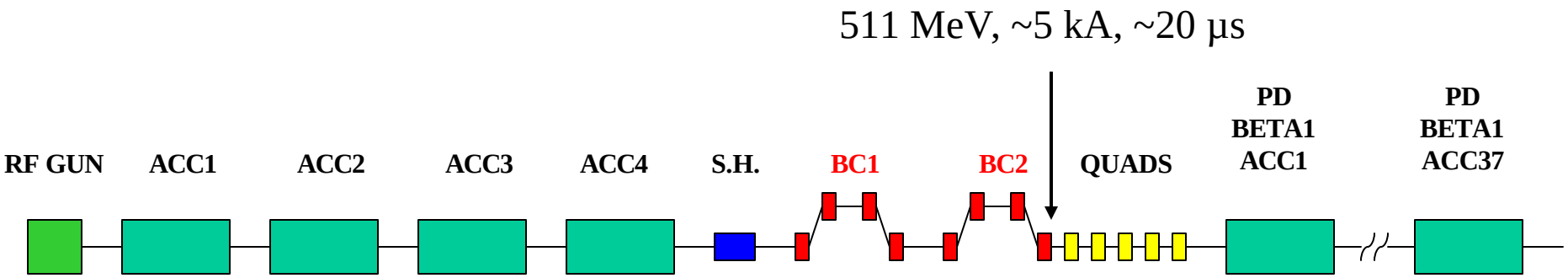
- **Jean-Paul Carniero**
  - In support and check of Linac design work by Petr Ostroumov and his RIA group at Argonne

TRACK vs. ASTR for H-



H- Through Entire Beta = 1 Linac Section

XFEL injector + Proton Driver Beta=1 (37 cryomodules)

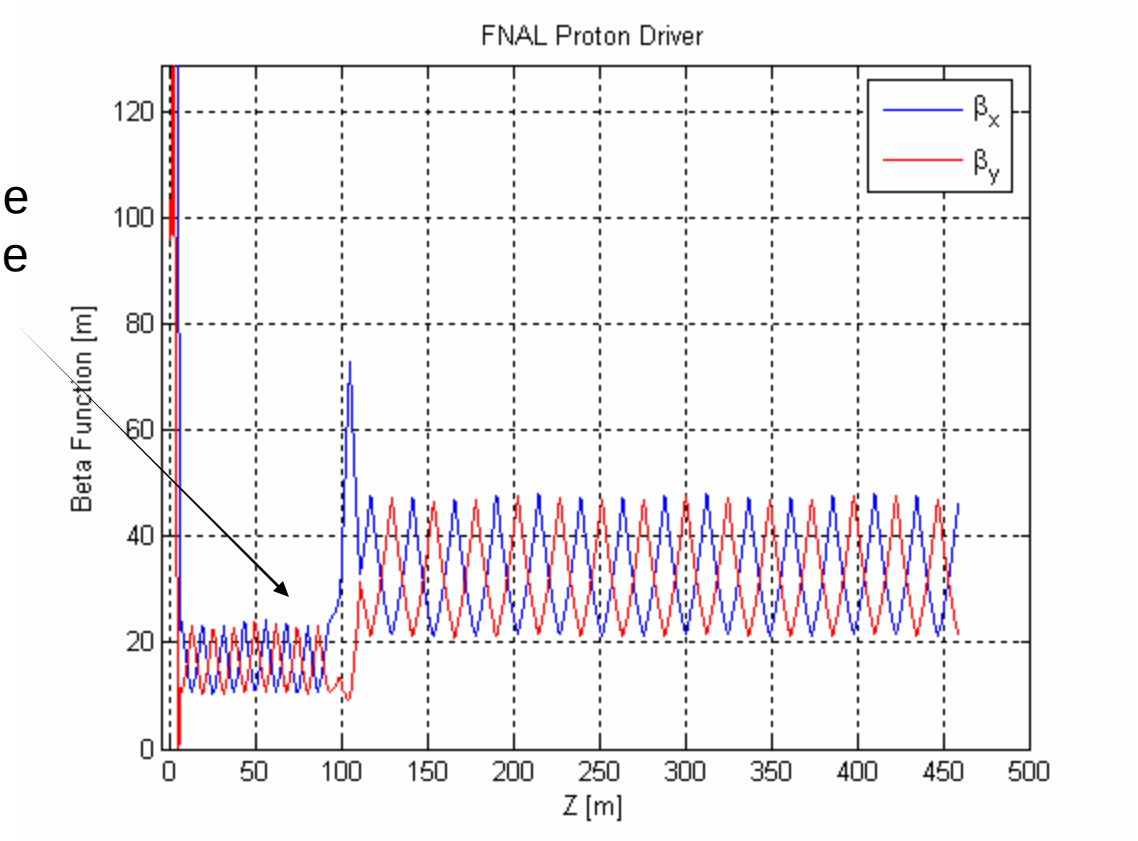


LASER	**Long = 20 ps Flat Top + 3ps rise time**
	Trans = 3 mm diameter
RF GUN	**40 MV/m, -2.8 deg w.r.t crest**
SOLENOIDS	**0.163 T**
ACC1	**4 × 13.65 MV/m @ -25 deg w.r.t on crest**
	4 × 22.22 MV/m @ -25 deg w.r.t on crest
ACC234	**20.22 MV/m @ -24.3deg w.r.t on crest**
S. H. (3.9 GHz)	**8 × 32.5 MV/m @ 160.6 deg w.r.t. on crest**

BC1	**4.25 deg**
BC2	**0.93 deg**
PD ACC1 to ACC37	**25 MV/m, on crest**

Electron Simulation

Change from 2 to 1 Quadrupole per Cryomodule



Electrons Through Entire Beta = 1 Linac

Some Other Activities

- **Doug Moehs, Henryk Piekarz, Chuck Schmidt**
  - H- Ion Source development
- **Milorad Popovic**
  - 50 KeV beam transport
- **Paul Czarapata, Leon Beverly, Jim Steimel and the Meson Building Crew**
- **Jerry Leibfritz, Maurice Ball, Steve Wesslen and Rob Reilly in AD Mechanical Support**
- **Apologies to all I've failed to include**

- **12 Accelerator Division FTE's effort in December !!!**

Some MI Investigations Under Alberto

- **Impedance Measurements & Pallatives**
  - Main Injector is ~7 yrs old
  - No Impedance Measurements Yet
  - Will key MI components need low-Z upgrades?
- **Gamma-T Jump Systems**
  - Main Injector
  - Booster
- **Collimation**
  - Main Injector (Momentum, & Betatron)
  - Recycler Stacking Collimators (Momentum & Betatron)

All these will be valuable independent of PD

Summary

- **There is considerable Accelerator Division activity now on Proton Driver design and R&D**
- **It should be an exciting year to bring 325 MHz klystron and RFQ on-line to accelerate beam in the Meson Detector Building**
- **Much of the Proton Driver activity will support plans for ILC systems and ILC Test Facilities**
  - Civil construction considerations
  - High power vector modulator and multiple cavity control development
- **MI efforts will lead to improvements even for present program**

8 GeV Superconducting Linac

With X-Ray FEL, 8 GeV Neutrino & Spallation Sources, LC and Neutrino Factory