8 GeV
Multi- Mission
Injector Linac

G. William Foster

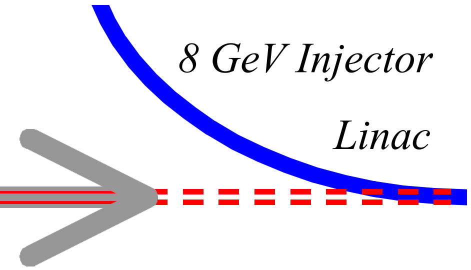
Proton Driver II Design Study

8 GeV Injector Linac

- Initiated by Fermilab Directorate
- Goal is 5x more protons in Main Injector.
- Side-by-side studies *(including cost)* of:
  - 8 GeV Booster Synchrotron
  - 8 GeV Superconducting Linac
  - Main Injector modifications for I_{BEAM} ~ 2 Amp

FNAL needs a "Main Injector Sized" project ~2005

8 GeV Injector Linac Concept



1) Copy SNS Linac design up to 1.2 GeV

(Reduced beam current and relaxed schedule allow some design optimizations)

2) Use "TESLA" Cryomodules from 1.2 $\rightarrow$ 8 GeV

3) H^- Injection at 8 GeV in Main Injector

$\Rightarrow$ "Super-Beams" in Fermilab Main Injector:

2 MW Beam power at 120 GeV, small emittances, and minimum (1.5 sec) cycle time

- Other possible missions for unused linac cycles:
  - 8 GeV ν program, 8 GeV electrons ==> XFEL, etc.

8 GeV Injector Linac - Possible Sitings

MI-30 Injection Point
Chosen for Design Study

8 GeV Linac Parameters

8 GeV LINAC

Energy	GeV	8	
Particle Type	H- Ions, Protons, or Electrons		
Rep. Rate	Hz	10	
Active Length	m	671	
Beam Current	mA	25	
Pulse Length	msec	1	
Beam Intensity	P / pulse	1.5E+14	(can be H-, P, or e-)
	P/hour	5.4E+18	
Linac Beam Power	MW avg.	2	
	MW peak	200	

MAIN INJECTOR WITH 8 GeV LINAC

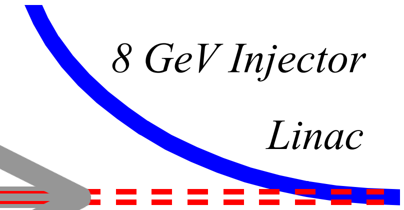
MI Beam Energy	GeV	120	
MI Beam Power	MW	2.0	
MI Cycle Time	sec	1.5	filling time = 1msec
MI Protons/cycle		1.5E+14	5x design
MI Protons/hr	P / hr	3.6E+17	
H-minus Injection	turns	90	SNS = 1060 turns
MI Beam Current	mA	2250	

Benefits of 8 GeV Injector

8 GeV Injector Linac

- Benefits to ν and Fixed-Target program
  - solves proton economics problem: > 5E18 Protons/hr at 8 GeV
  - operate MI with small emittances, high currents, and low losses
- Benefits to Linear Collider R&D
  - 1.5% scale demonstration of TESLA economics
  - Evades the Linear Collider R & D funding cap
  - Simplifies the Linear Collider technology choice
  - Establishes stronger US position in LC technology
- Benefits to Muon Collider / n-Factory R&D
  - Establishes cost basis for P-driver and muon acceleration
- Benefits to VLHC: small emittances, high Luminosity
  - ~4x lower beam current reduces stored energy in beam
  - Stage 1: reduces instabilities, allows small beam pipes
  - Stage 2: injection at final synchrotron-damped emittances

Main Injector with 8 GeV Linac



- 1.5 Second Cycle time to 120 GeV
  - filling time 1 msec or less
  - no delay or beam gaps for multiple Booster Batches
- H^- stripping injection at 8 GeV
  - 25 mA linac beam current
  - 90-turn Injection gives MI Beam Current ~2.3 A

    (SNS has 1060 turn injection at 1 GeV)
  - phase space painting needed at high currents

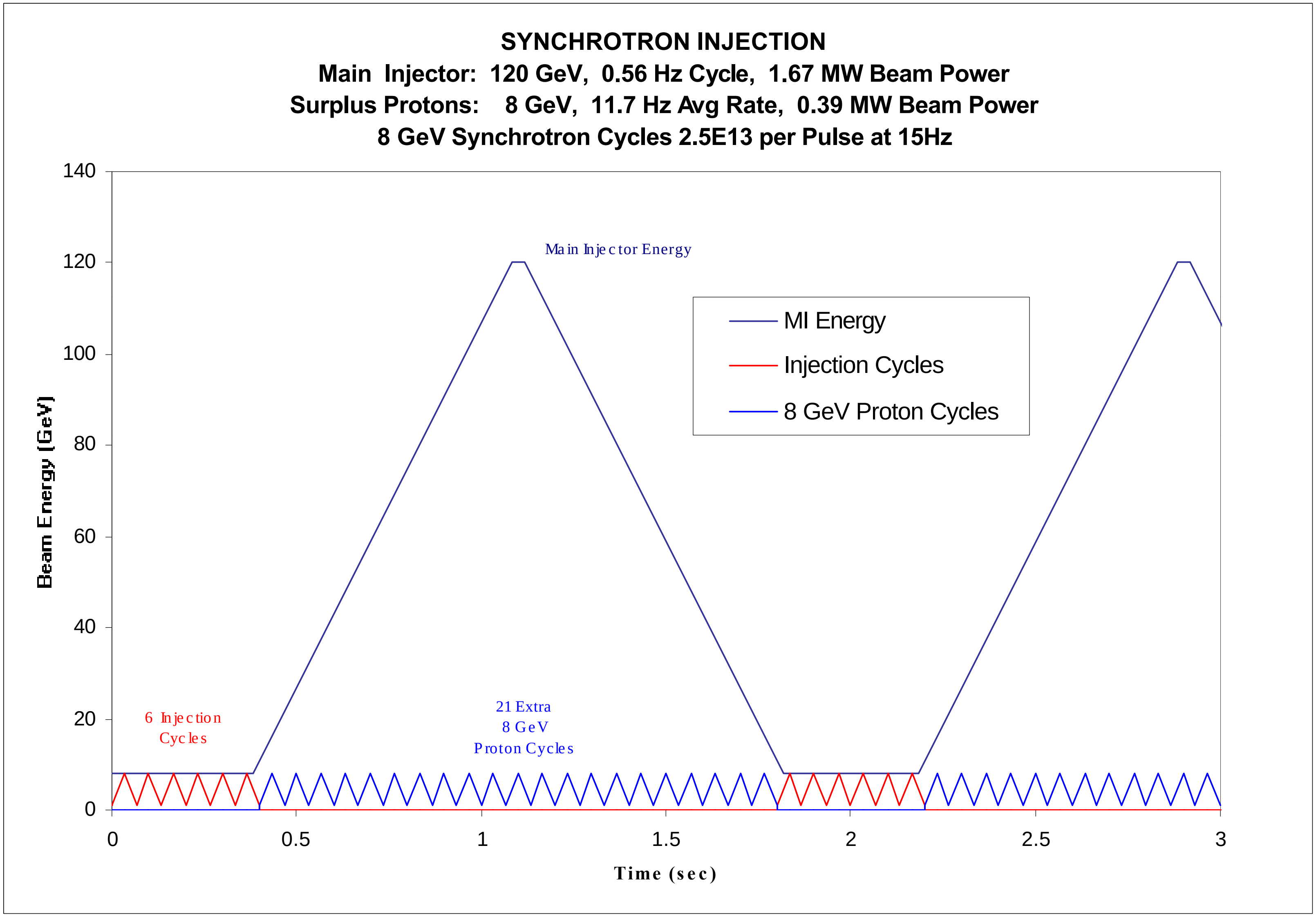
® *can put a frightening amount of beam in MI*

- Very small emittances possible at low currents

120 GeV Main Injector Cycle with 8 GeV Synchrotron

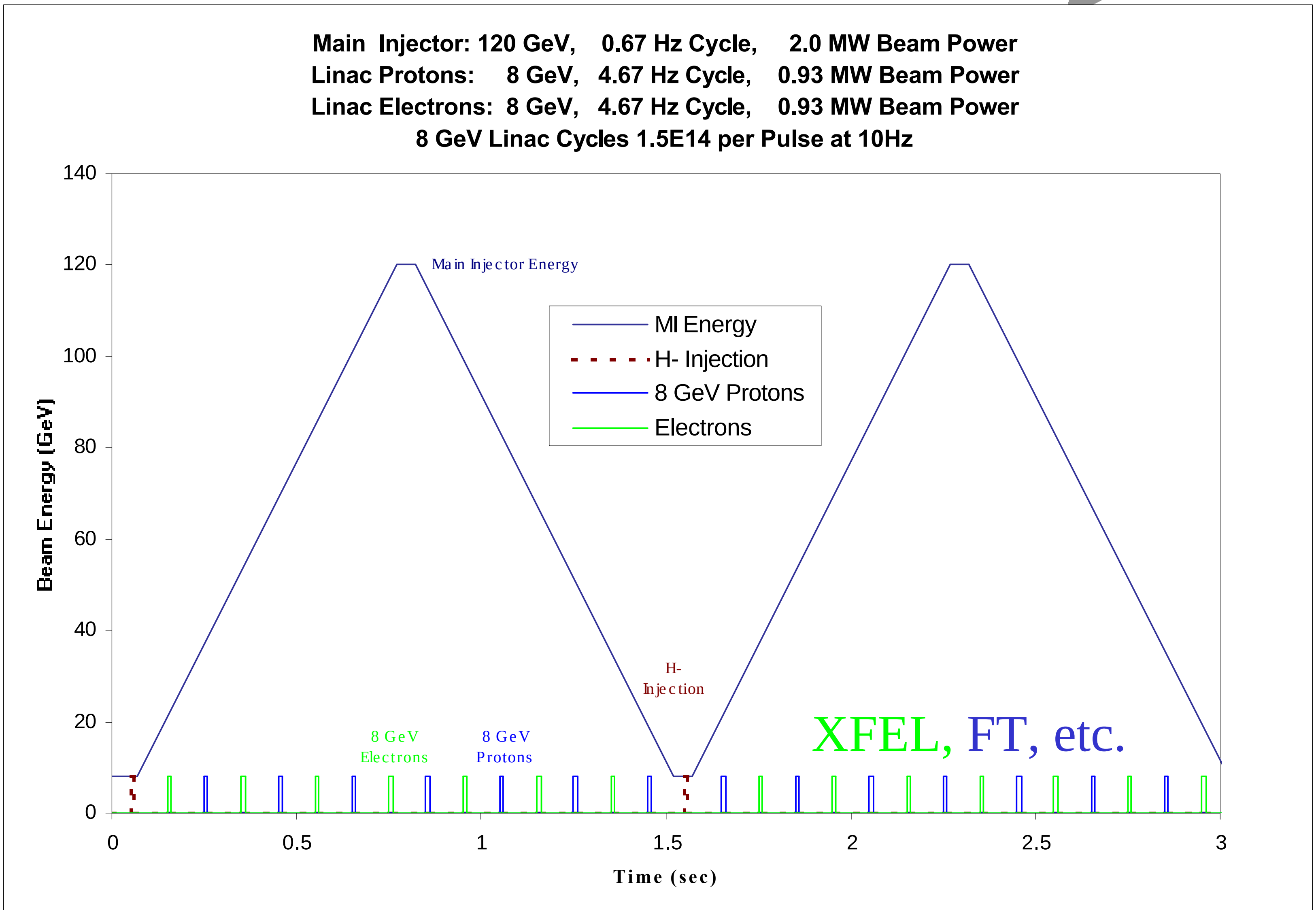
8 GeV Injector

Linac

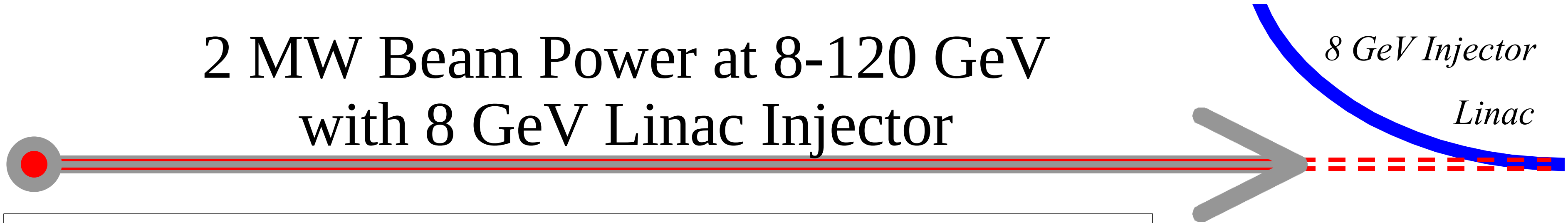


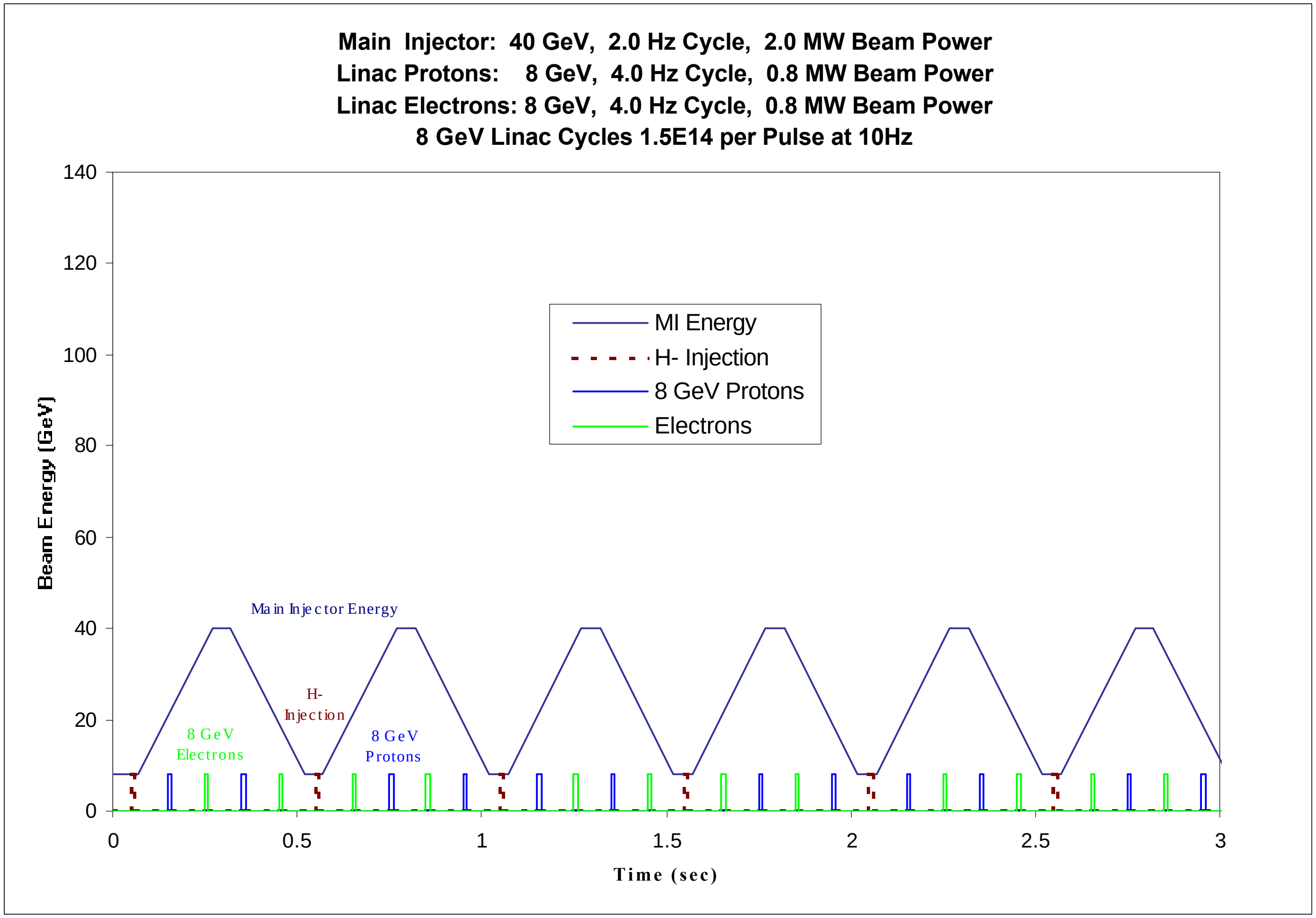
120 GeV Main Injector Cycle with 8 GeV Linac, e- and P

8 GeV Injector Linac



2 MW Beam Power at 8-120 GeV with 8 GeV Linac Injector

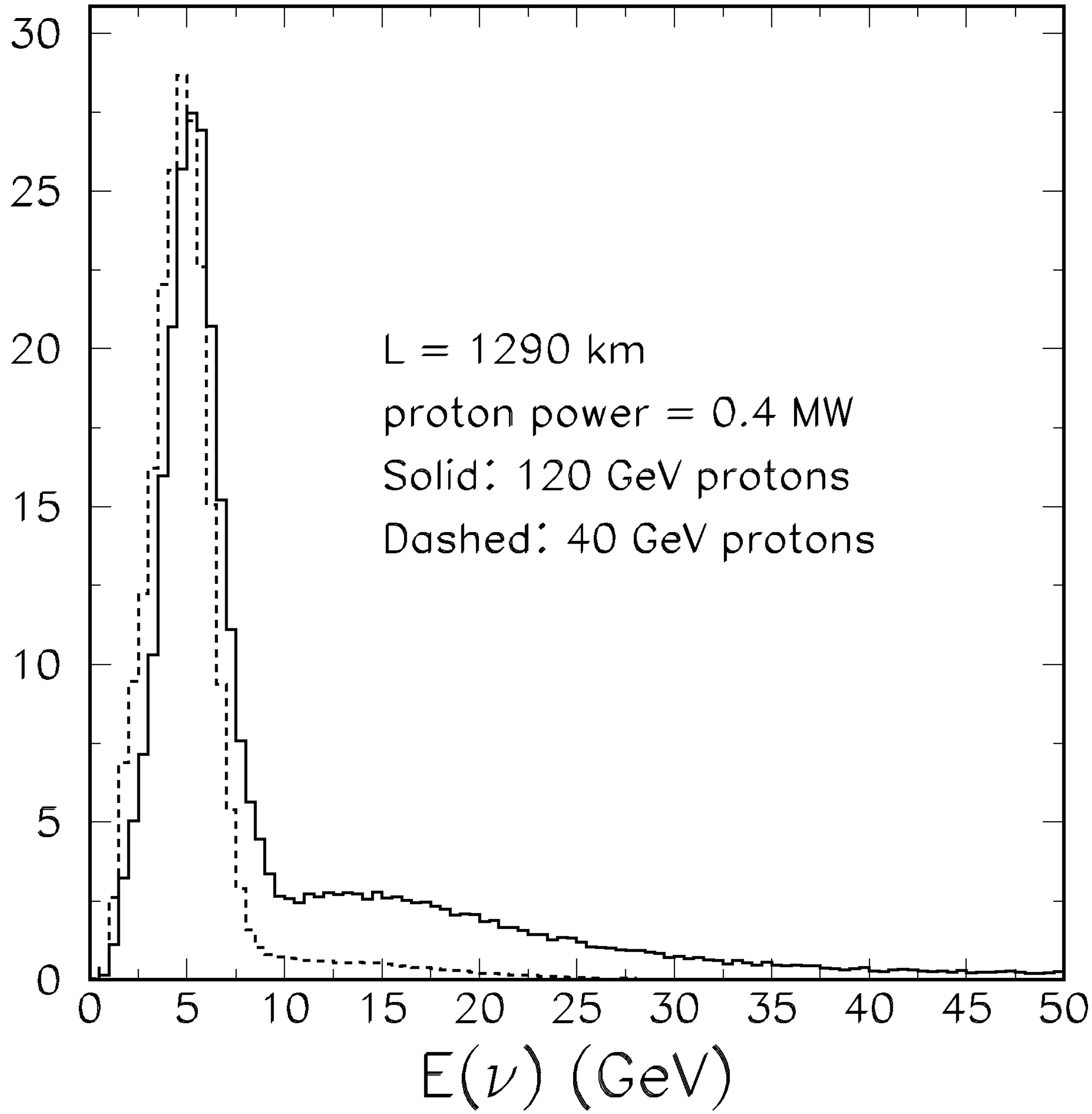




Energy Variability Important to Flexible Neutrino Program

MI cycles to 40 GeV at 2Hz, retains 2 MW MI beam power

Running at Reduced Proton Energy Produces a Cleaner Neutrino Spectrum



Running at 40 GeV reduces tail at higher neutrino energies.

Same number of events for same beam power.

(Plot courtesy Fritz & Debbie)

Very Rough Cost Estimates

1) Scaled from TESLA costs

2) Scaled from SNS actual costs

3) Procedure for bottom-up cost est.

– use SNS actual costs where reasonable

– independent, bottom-up cost estimates elsewhere

– *Not yet completed but this is the way to go.*

Rough Cost, Scaled from TESLA

- TESLA Project Cost (European) $3B
- subtract damping rings, IR, Injector $2.5B
- US Cost Basis (x2) for bare linac $5B
- Scale to 7 GeV (7/500) = 1.4% $70M
- TESLA Quantity Discount $(7/500)^{-0.074} = 1.37$ $100M
- Include Fixed Project Cost ($50M??) **$150M**

Rough Cost, Scaled from SNS

8 GeV Injector Linac

- SNS Project Cost $1300M
- SC Linac Cost (approx, incl. civil) $250M
- Scale SCRF by energy (7.6/0.8) x10

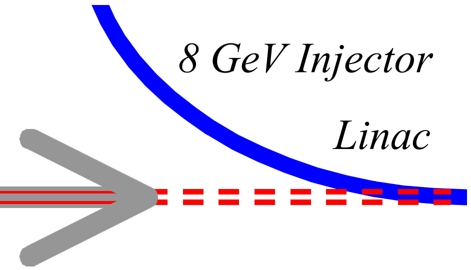
$2.5 B

There are many good technical reasons why the TESLA linac should be cheaper. But how much?

We need detailed breakdowns to understand the apparent disconnect between TESLA and SNS cost estimates.

Bottom-up Cost for 8 GeV Linac

the game plan:



- Can use SNS <u>Actual</u> Costs for:
  - Niobium
  - Finished Cavities (industrially produced)
  - RF Couplers, Tuners, final Chemistry & Test
  - Klystrons, circulators, waveguide, etc.
  - Cryogenics and Cryoplant including civil
- T. Nicol independent cost est. for TESLA style Cryostat, and Assembly
- FNAL Cost Est. for TESLA-Style Modulators
- MI actual costs for tunnel, Beam Dump, etc.
- FMI for Controls & Project Overhead

Design Optimizations of SNS Linac

- The Spallation Neutron Source (SNS) is a well organized and documented project, and a good model for many aspects of the 8 GeV Linac.
- Design optimizations possible for 8 GeV Injector:
  - Lower average beam current and pulse rate (10 Hz vs. 60Hz)
  - Higher accelerating gradients can be assumed due to successful SC Cavity R&D by SNS, TJNAF, TESLA, Cornell, KEK, et.al.
  - Less schedule pressure allows for additional component development where cost-effective
- 8 GeV Linac can marry the best of TESLA, CEBAF, and SNS system designs

Which Optimizations of SNS are worth it?

8 GeV Injector Linac

1) TESLA-style RF fanout

– drive many (8-12) cavities from single big klystron

– must complete SNS development of fast phase shifter

2) Eliminate warm Cavity-Coupled Linac (CCL)

– Use Beta=0.47, 805 MHz Superconducting cavities developed for RIA project by NSCL/Jlab/INFN

– Similar cryomodules & RF as Beta=0.61, 0.81 cavities

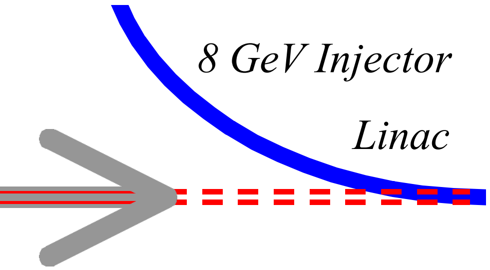
– SNS considered this but dropped due to schedule

3) Use TESLA-style cryomodules with cold quads

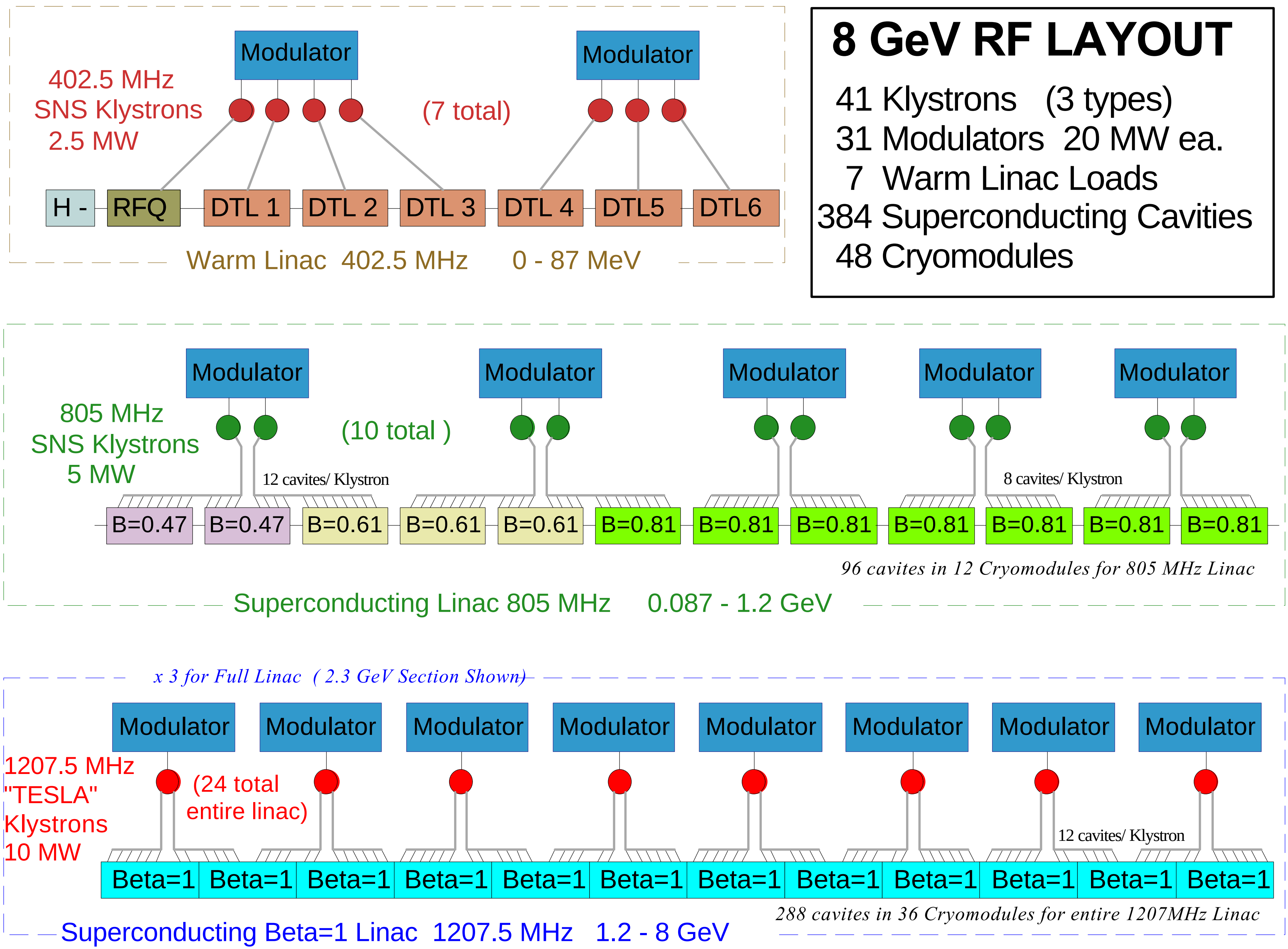
– longer cryomodules with fewer end costs

4) Civil construction for fewer klystrons per meter

Layout of 8 GeV Linac

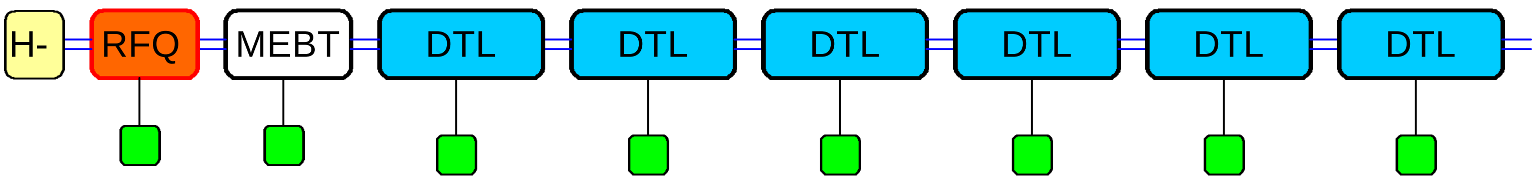


- Copy SNS Front-end, RFQ, DTL up to 87 MeV
- 805 MHz Superconducting Linac up to 1.2 GeV
  - Three sections: Beta = 0.47, 0.61, 0.81
  - Use cavity designs developed for SNS & RIA
  - TESLA-style cryomodules for higher packing factor
- 1.2 GHz “TESLA” cryomodules from 1.2-8 GeV
  - This section can accelerate electrons as well
  - RF from one Klystron fanned out to 12 cavites


8 GeV RF LAYOUT
41 Klystrons (3 types)
31 Modulators 20 MW ea.
7 Warm Linac Loads
384 Superconducting Cavities
48 Cryomodules
402.5 MHz
SNS Klystrons
2.5 MW
Modulator
Modulator
(7 total)
H -
RFQ
DTL 1
DTL 2
DTL 3
DTL 4
DTL5
DTL6
Warm Linac 402.5 MHz 0 - 87 MeV
805 MHz
SNS Klystrons
5 MW
Modulator
Modulator
Modulator
Modulator
Modulator
(10 total)
12 cavites/ Klystron
8 cavites/ Klystron
B=0.47
B=0.47
B=0.61
B=0.61
B=0.61
B=0.81
B=0.81
B=0.81
B=0.81
B=0.81
B=0.81
B=0.81
96 cavites in 12 Cryomodules for 805 MHz Linac
Superconducting Linac 805 MHz 0.087 - 1.2 GeV
x 3 for Full Linac (2.3 GeV Section Shown)
Modulator
Modulator
Modulator
Modulator
Modulator
Modulator
Modulator
Modulator
1207.5 MHz
"TESLA"
Klystrons
10 MW
(24 total
entire linac)
12 cavites/ Klystron
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
288 cavites in 36 Cryomodules for entire 1207MHz Linac
Superconducting Beta=1 Linac 1207.5 MHz 1.2 - 8 GeV

Linac: 0 - 87 MeV

<u>Copy of SNS Front End and Drift-Tube Linac (DTL)</u> **0 ® 87 MeV**



Eight 402.5 MHz, 2.5 MW Klystrons   **Total Length ~45m**

- Direct Copy of SNS Design:
  - Ion Source
  - RF Quadrupole (RFQ)
  - Medium Energy Beam Transport: buncher (&chopper?)
  - Drift Tube Linac (402.5 MHz Normal Conducting)

SNS work provides technical existence proof

At Reduced RF Duty Cycle of ~1%, the Front End is a Commercial Product

8 GeV Injector

Linac

ACCSYS TECHNOLOGY, INC

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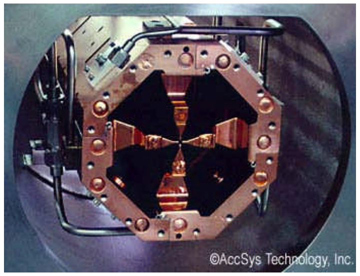
CUSTOM LINAC SYSTEMS

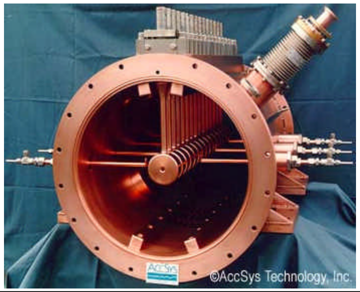
AccSys' proprietary and patented linac technology can provide a wide range of ion beams and energies for specialized applications in research and industry. AccSys experts will design a system to customer specifications consisting of a carefully selected combination of our standard modular subsystems: radiofrequency quadrupole (RFQ) linacs, drift tube linacs (DTL), rf power systems and/or other components such as high energy beam transport (HEBT) systems and buncher cavities.

Radio Frequency Quadrupole Linacs



AccSys' patented Univane (US Patent No. 5,315,120) design provides a robust, cost-effective solution for low-velocity ion beams. This unique geometry incorporates four captured rf seals, is easy to machine, assemble and tune, and is inexpensive to fabricate. The extruded structure, which is available in lengths up to three meters, can accelerate ions injected at 20 to 50 keV up to 4 MeV per nucleon. Cooling passages in the structure permit operation at duty factors up to 25%.

Drift Tube Linacs

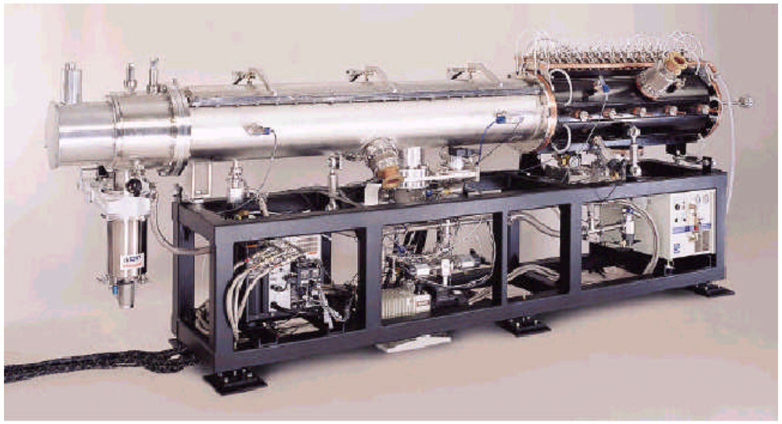


Drift Tube Linacs provide a cost-effective solution for ion beam energies above a few MeV per nucleon. Designed to accelerate ions from an RFQ, the DTL's permanent magnet focusing and high rf efficiency result in a minimum cost per MV. AccSys' patented drift tube mounting scheme (US Patent No. 5,179,350), which is integral to the twin-beam welded vacuum tank, provides excellent mechanical stability and low beam loss.

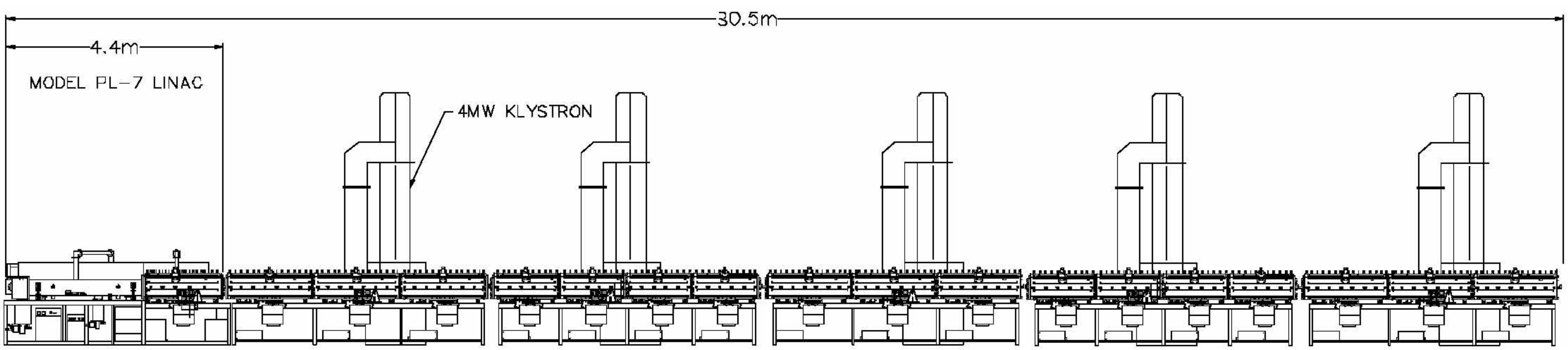
D. Young's work...

AccSys Source/RFQ/DTL

8 GeV Injector Linac



- AccSys PL-7 RFQ with one DTL tank

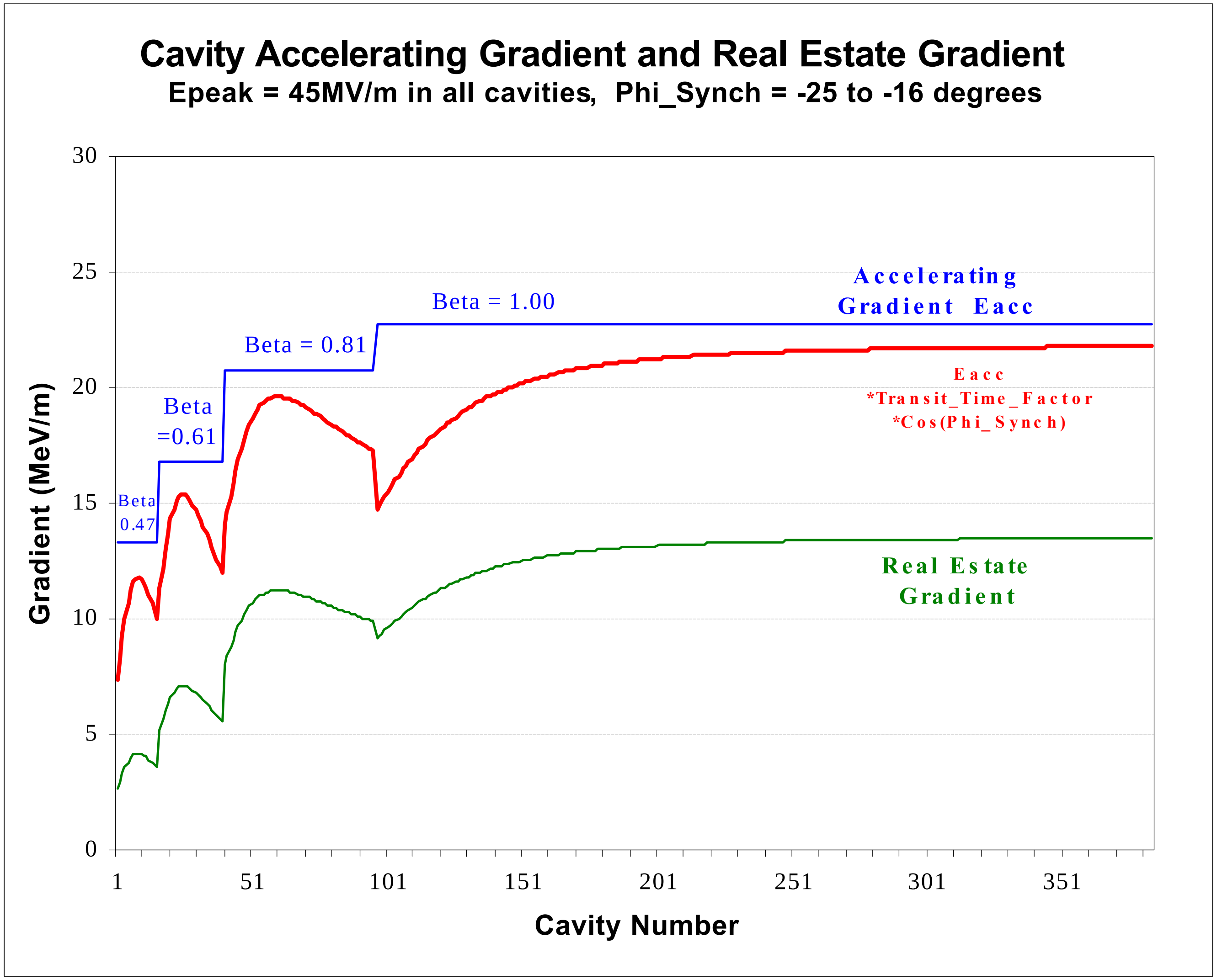


- Appears to have shorter length and lower price than cloning the SNS Linac, *for 10 Hz operation*

D. Young's work...

Superconducting Cavity Gradients

8 GeV Injector Linac



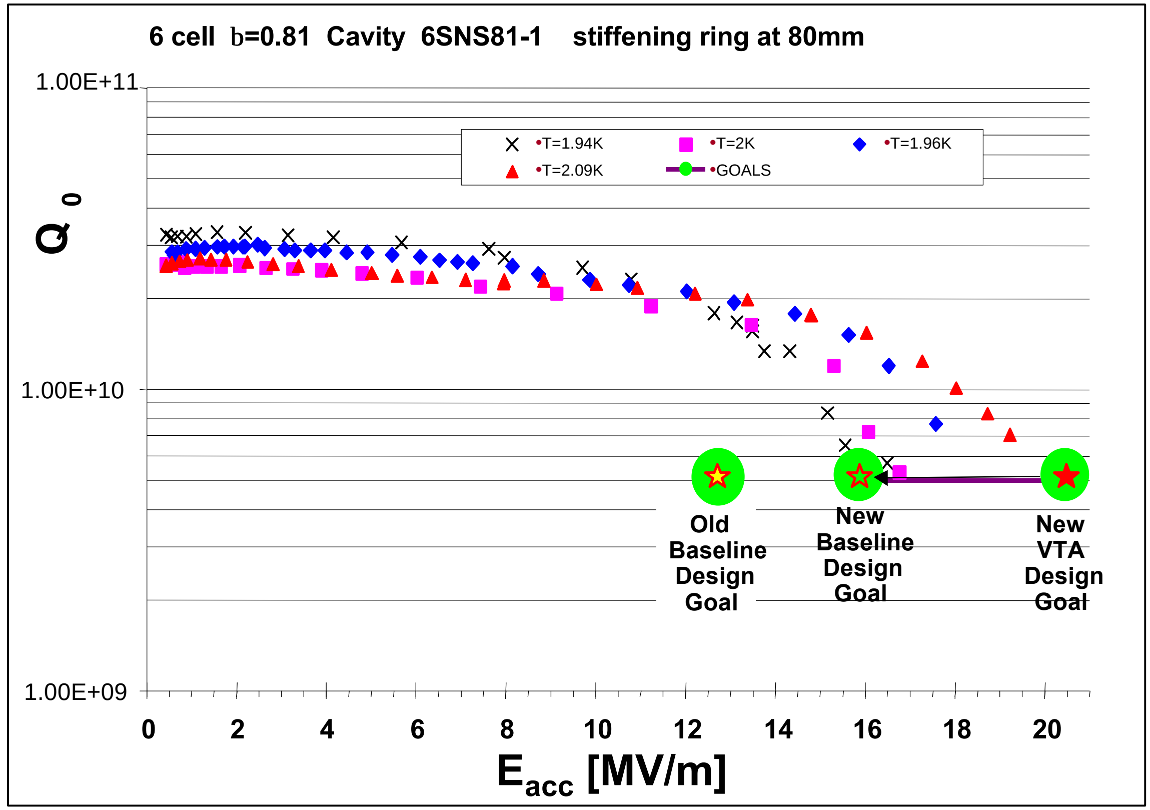
8 GeV design assumes *peak* field in cavities of 45 MV/m.

SNS:
37.5 MV/m

TESLA(500):
47 MV/m

TESLA(800):
~70 MV/m

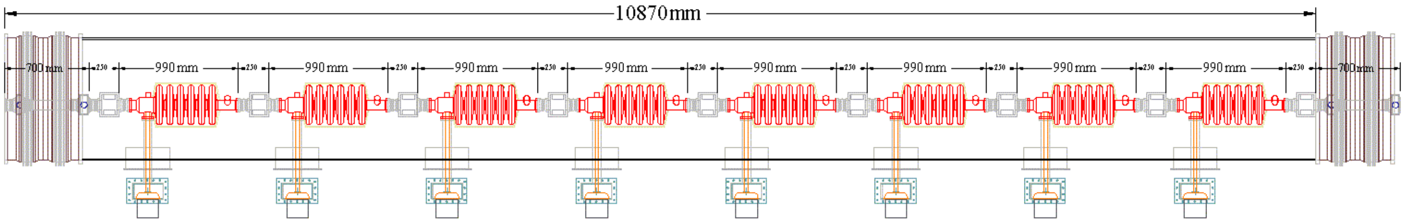
SNS $\beta = 0.81$ Tests at TJNAF



[from N. Holtkamp Nov '01 SNS Review]

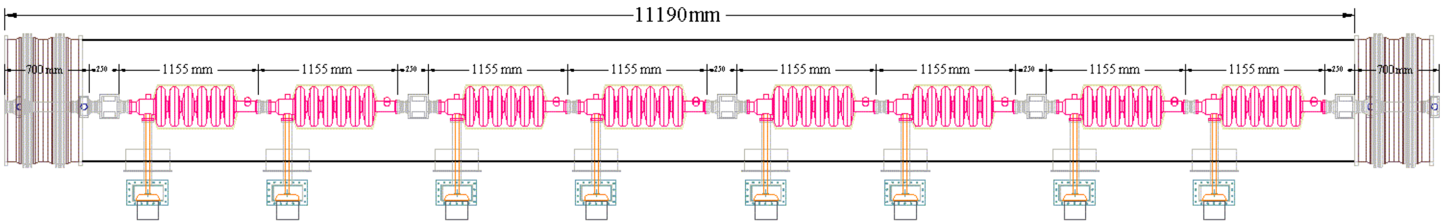
Eacc > 20 MV/m for protons is now reasonable design goal

8 GeV Linac Cryomodules - 4 Types



Beta= 0.47 (RIA)

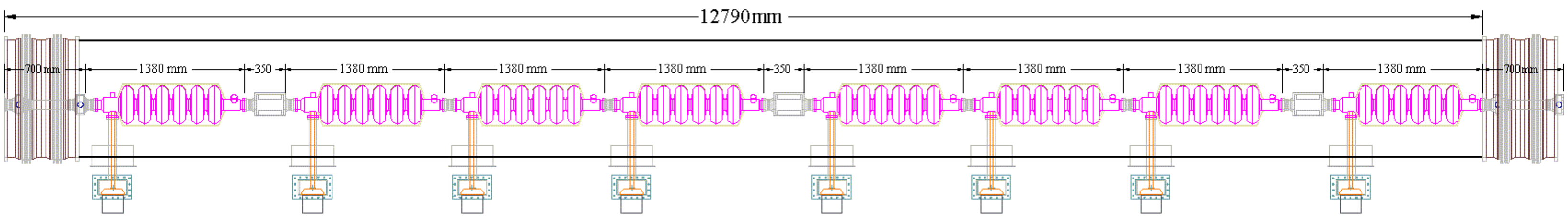
87-175 MeV
2 Cryomodules
16 Cavities (RIA)



Beta= 0.61 (SNS)

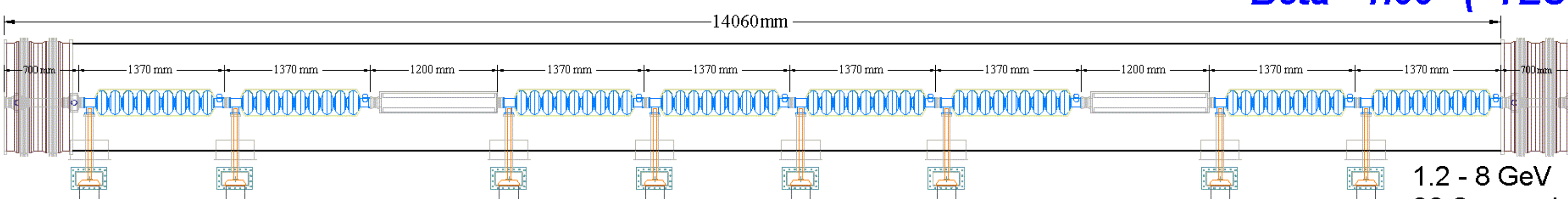
175 - 400 MeV
3 Cryomodules
24 Cavities

Beta= 0.81 (SNS)



0.4 - 1.2 GeV
7 Cryomodules
56 Cavities

Beta= 1.00 ("TESLA")

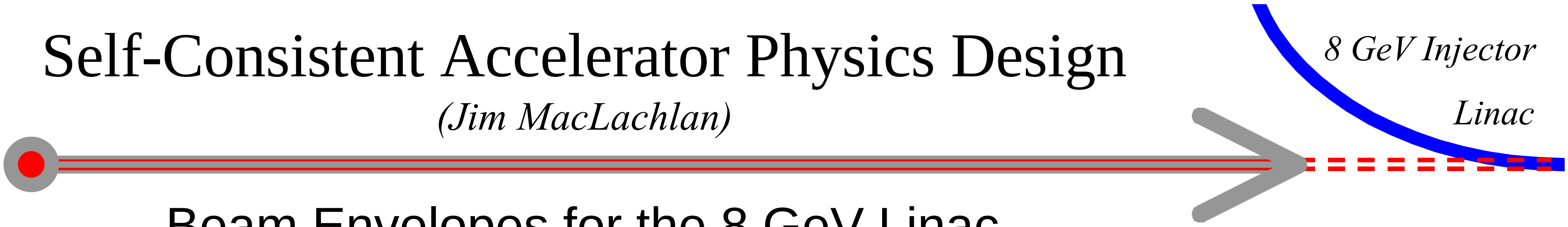


1.2 - 8 GeV
36 Cryomodules
288 Cavities

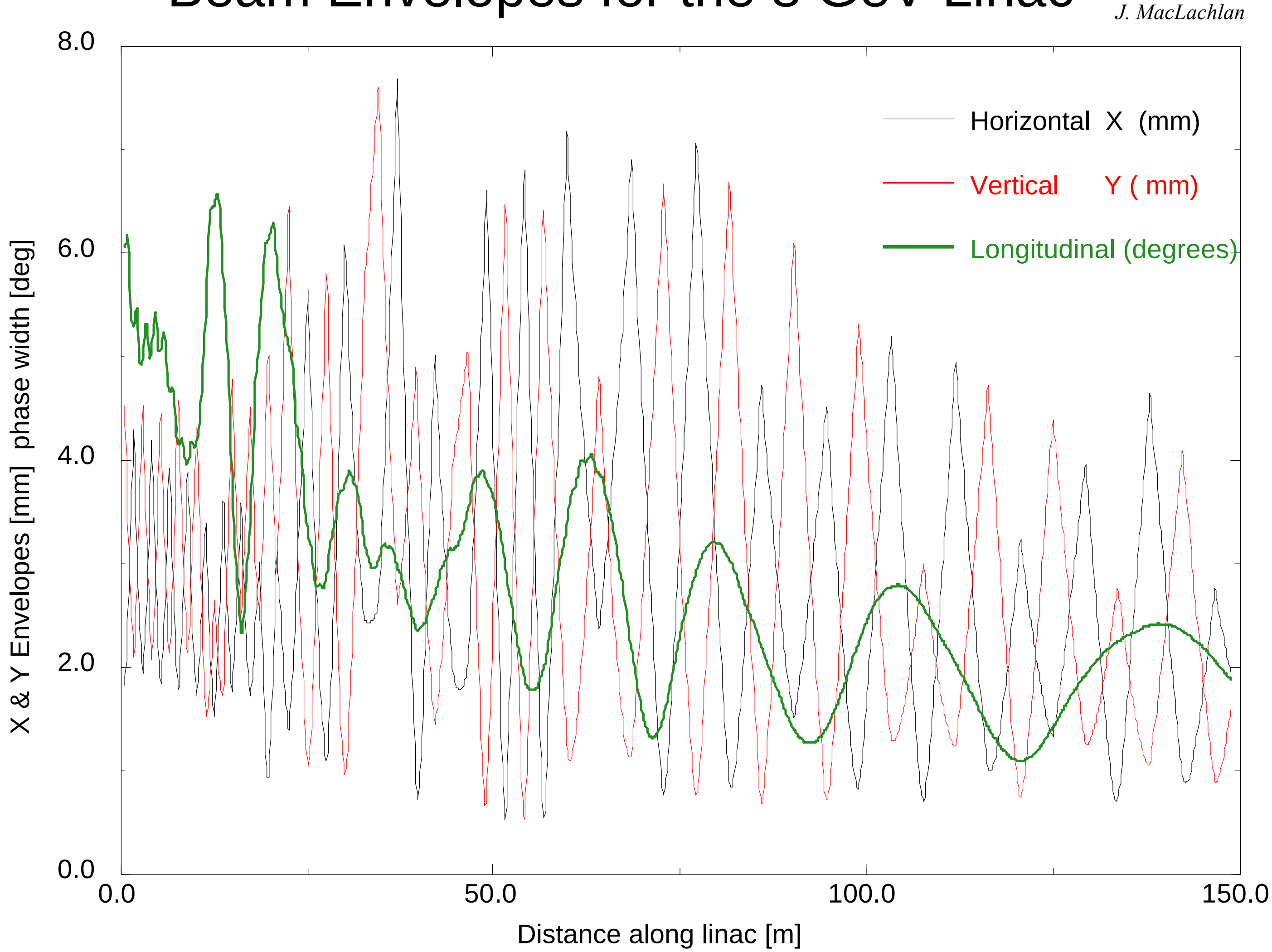
9 Cell Beta=1 Cavities, 1207.5 MHz

Self-Consistent Accelerator Physics Design

(Jim MacLachlan)



Beam Envelopes for the 8 GeV Linac



Had to increase number of quads to get to good design...

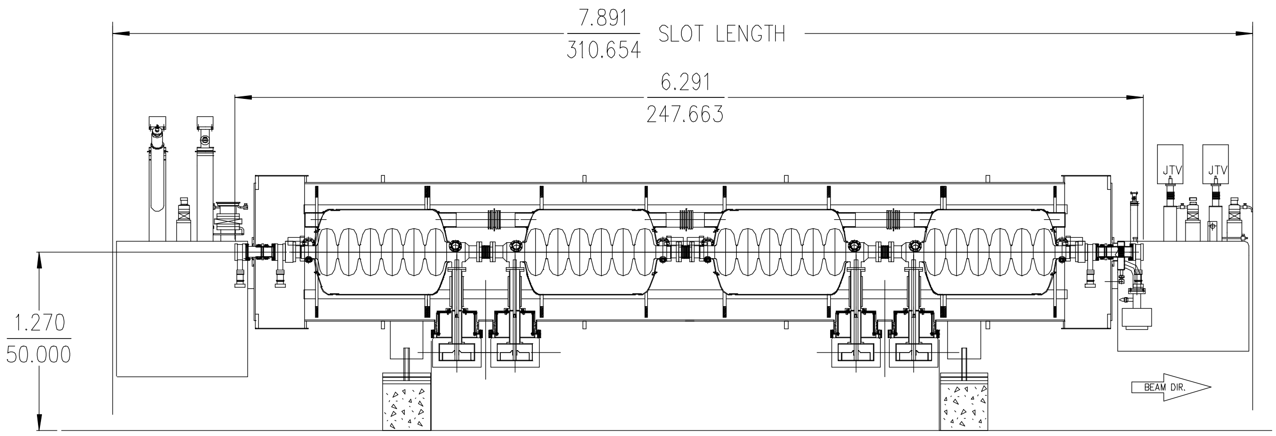
CRYOMODULES

<u>BIG Differences between SNS & TESLA</u>

- Key Specification:
  - SNS Cryomodules can be swapped out in *<u>~1 shift</u>*
  - TESLA cryomodule replacement takes ~*<u>25 days</u>* *
    - comes from having 2.5 km section of linac
  - 8 GeV LINAC: *<u>~2 day</u>* repair time specified
    - possible because linac sector is much shorter ~300 m

* http://tesla.desy.de/new_pages/TESLA_Reports/2001/pdf_files/tesla2001-37.pdf

SNS/CEBAF Cryomodules

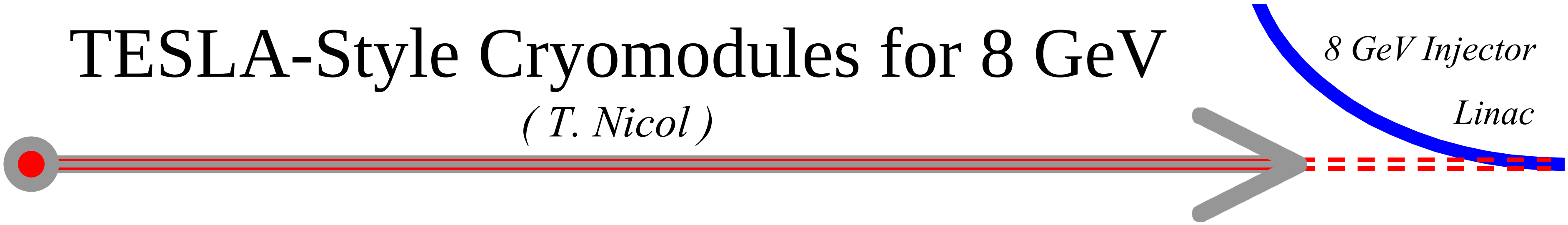


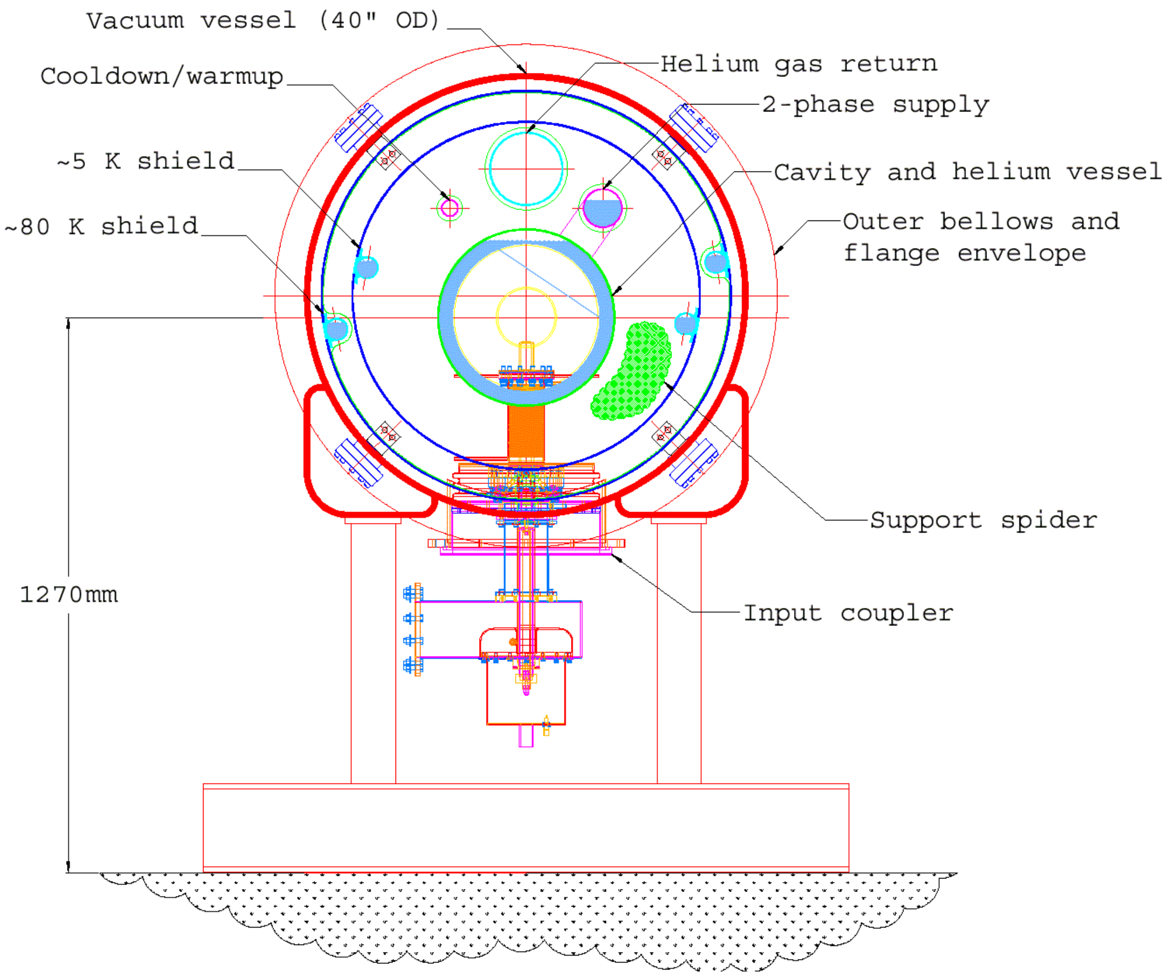
- Warm-to-cold beam pipe transition in each module
- 2K Coldbox, J-T & HTX in each Cryomodule
- Bayonet disconnects at each coldbox
- Only 3-4 cavities per cryomodule: ~50% fill factor

Expensive Design forced by fast-swap requirement

TESLA-Style Cryomodules for 8 GeV

(T. Nicol)



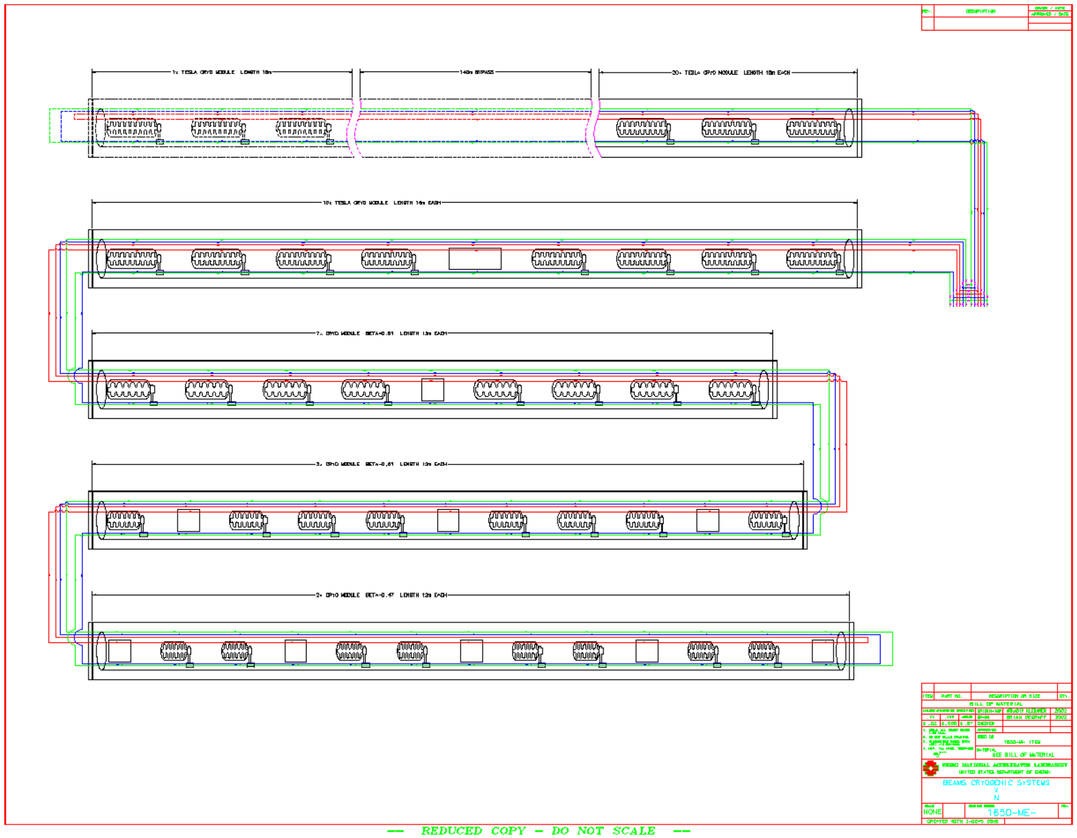


- Design conceptually similar to TESLA
- No warm-cold beam pipe transitions
- No need for large cold gas return pipe
- Cryostat diameter *smaller* than TESLA (~ same as LHC)
- RF Couplers are KEK/SNS design, conductively cooled

CRYOGENICS & CRYO PLANT

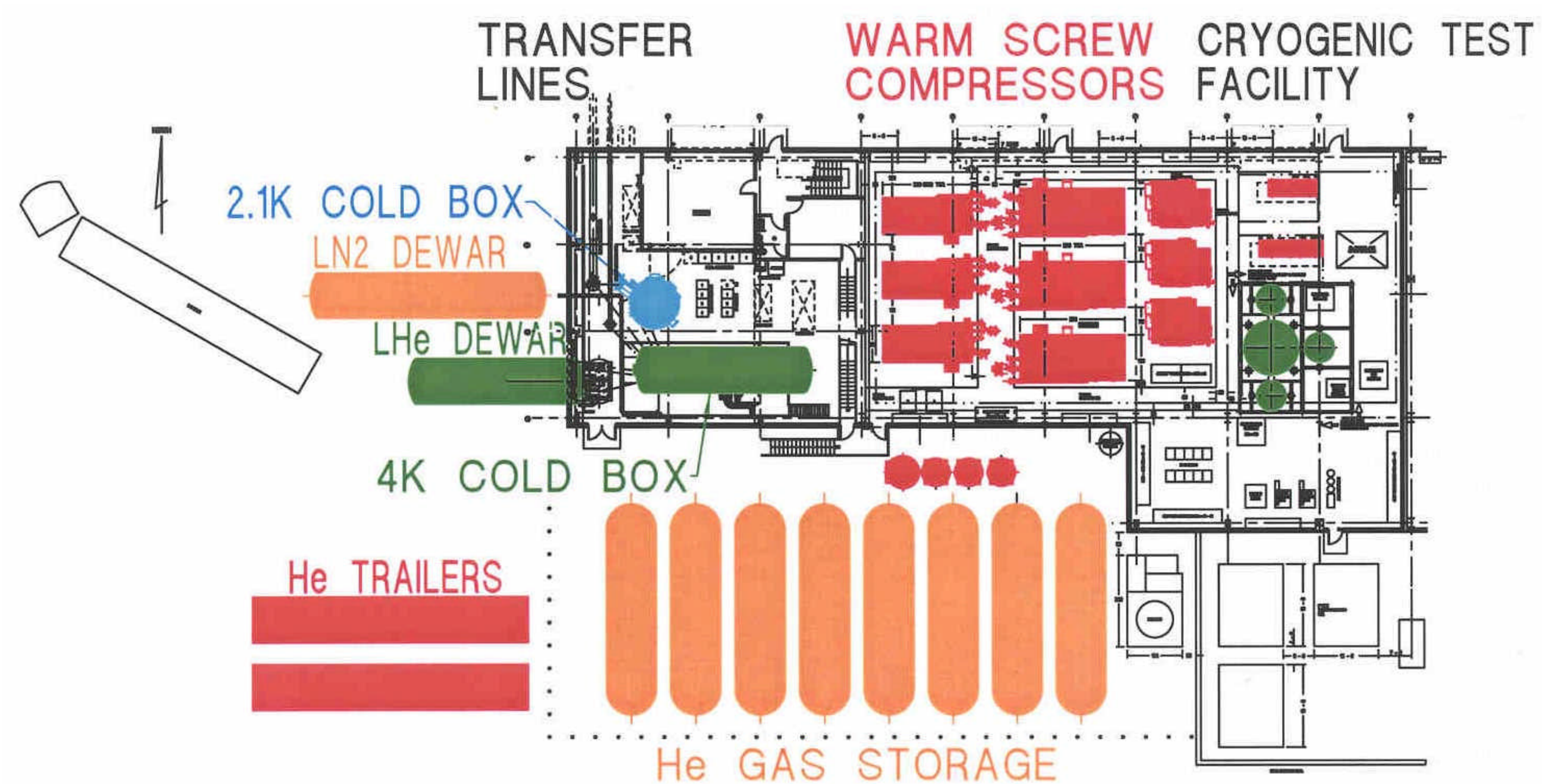
- 8 GeV Linac Cryoplant is ~ same size as SNS
  - Linac is longer: 8 GeV vs. 1 GeV
  - RF Duty Cycle is smaller 1% vs. 6%
    - *Dynamic heat load is about the same*
- 8 GeV Linac Static heat leak per meter is similar to TESLA (TTF)
  - No bayonet or cold box heat loads per cryomodule
    - *Standby heat load should be < ~ SNS*

CRYOGENICS & CRYO PLANT



- Arkadiy Klebaner is doing detailed analysis of 8 GeV linac cryogenic requirements & cost

SNS CHL Facility



8 GeV Linac Cryoplant will be comparable ~$15M

RF System for 1→ 8 GeV Linac

8 GeV Injector Linac

- Assume the TESLA-style RF distribution works

  This will require development of fast phase shifters for individual cavity control

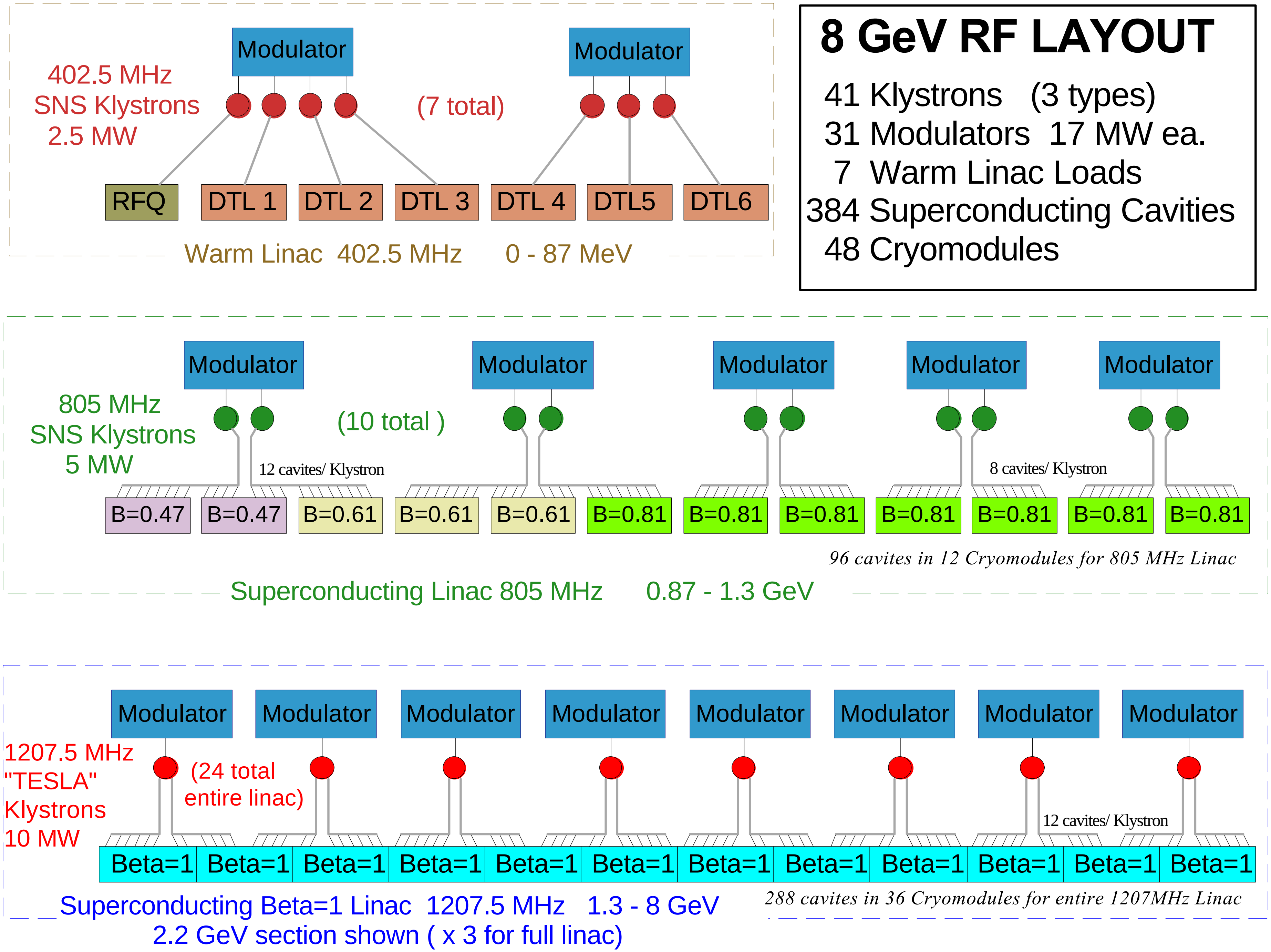
- One TESLA multi-beam Klystron per 12 Cavities
  - 24 Klystrons 10 MW each
  - 24 Modulators 20 MW Each
  - 288 total power couplers 600kW each
- Modulators are identical to TESLA modulators
- Rough Cost: $1.5M / RF station ⇒ $45M

  (TESLA costs & scaling rule* gives ~ $31M)

*cost proportional to $(\text{quantity})^{-0.074}$

Modulators for Klystrons

- Biggest component in RF costs
- Pfeffer, Wolff, & Co. have been making TESLA spec modulators for years
- FNAL Bouncer design in service at TTF since 1994
- $1M ea.



8 GeV RF LAYOUT
41 Klystrons (3 types)
31 Modulators 17 MW ea.
7 Warm Linac Loads
384 Superconducting Cavities
48 Cryomodules
Modulator
Modulator
402.5 MHz
SNS Klystrons
2.5 MW
(7 total)
RFQ
DTL 1
DTL 2
DTL 3
DTL 4
DTL5
DTL6
Warm Linac 402.5 MHz 0 - 87 MeV
Modulator
Modulator
Modulator
Modulator
Modulator
805 MHz
SNS Klystrons
5 MW
(10 total)
12 cavites/ Klystron
8 cavites/ Klystron
B=0.47
B=0.47
B=0.61
B=0.61
B=0.61
B=0.81
B=0.81
B=0.81
B=0.81
B=0.81
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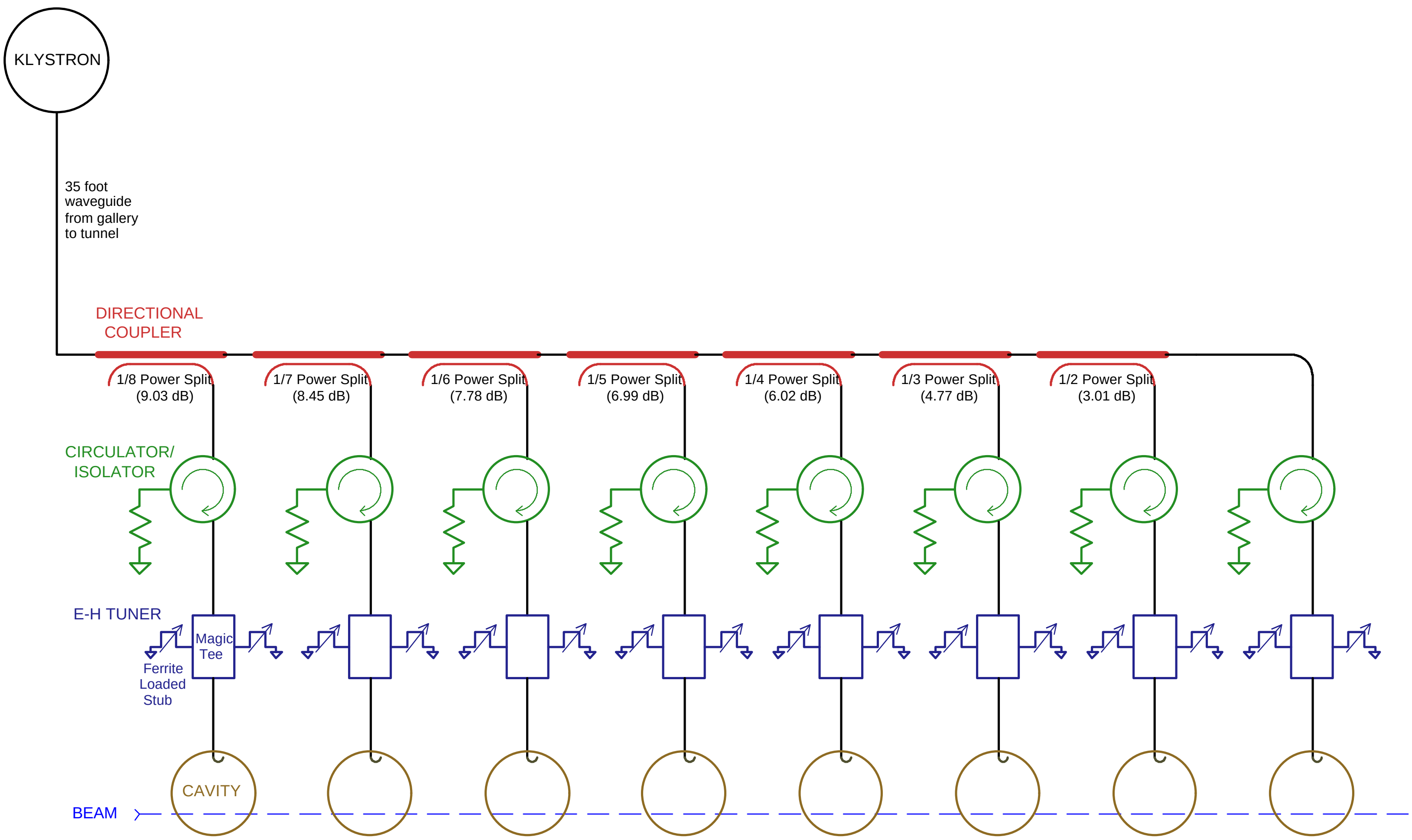
96 cavites in 12 Cryomodules for 805 MHz Linac
Superconducting Linac 805 MHz 0.87 - 1.3 GeV
Modulator
Modulator
Modulator
Modulator
Modulator
Modulator
Modulator
Modulator
1207.5 MHz
"TESLA"
Klystrons
10 MW
(24 total
entire linac)
12 cavites/ Klystron
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
Beta=1
288 cavites in 36 Cryomodules for entire 1207MHz Linac
Superconducting Beta=1 Linac 1207.5 MHz 1.3 - 8 GeV
2.2 GeV section shown (x 3 for full linac)

RF Fan-out for 8 GeV Linac

A. Moretti, D. Wildman

8 GeV Injector Linac



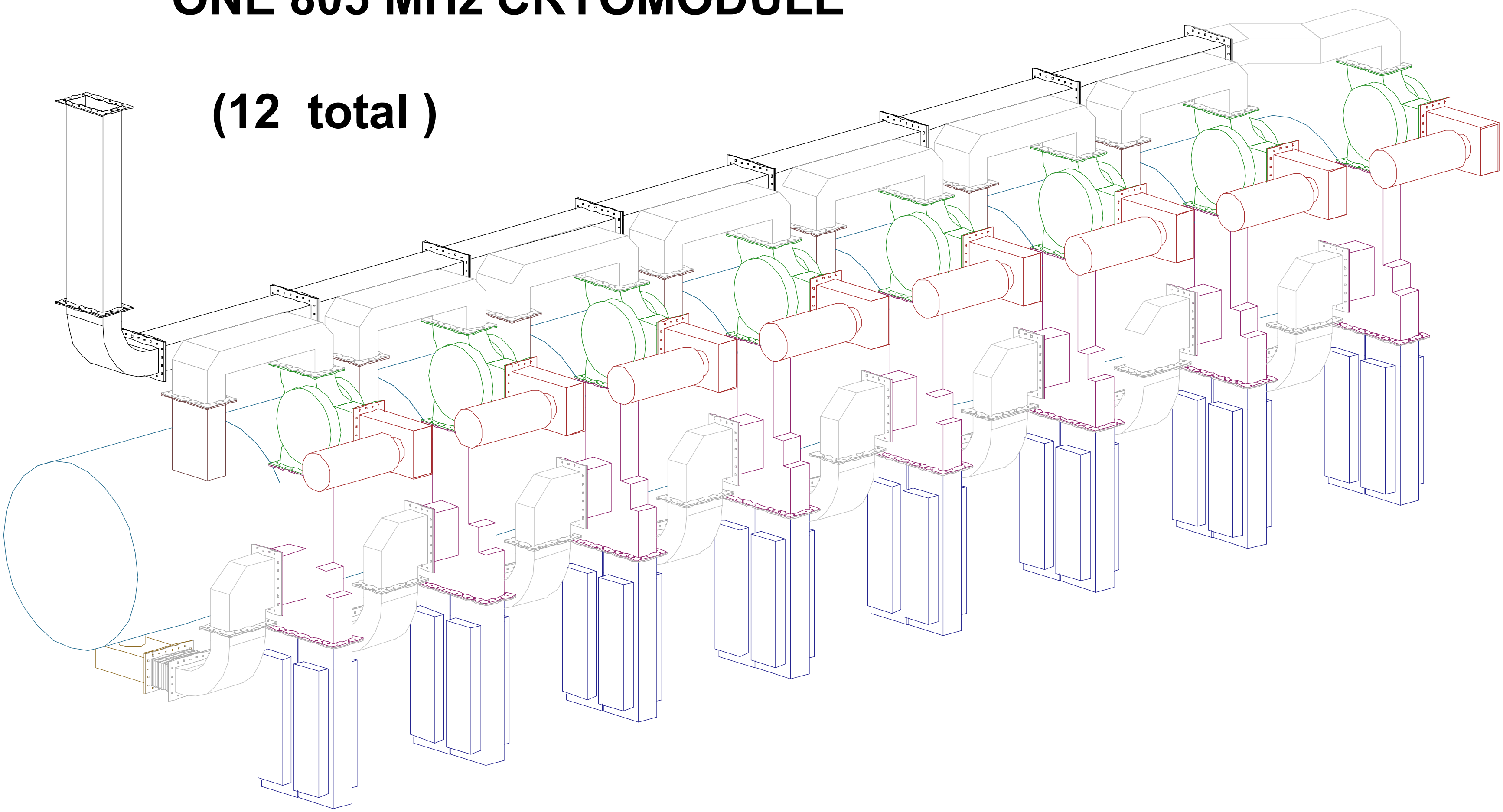
805 MHz RF Distribution in Tunnel

8 GeV Injector

Linac

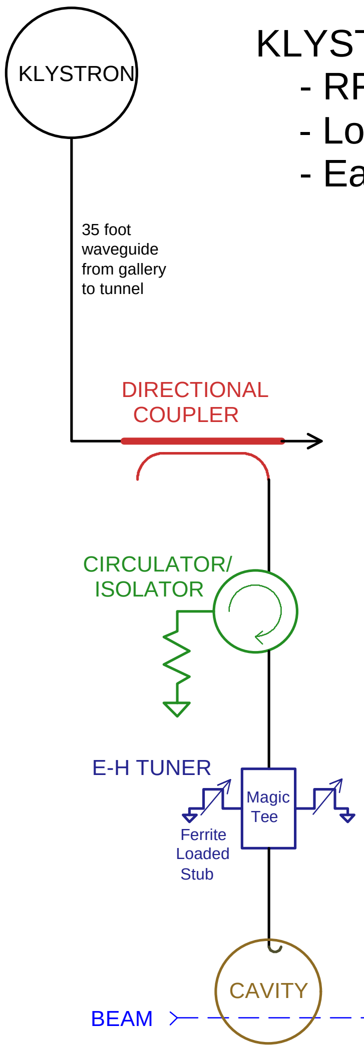
RF DISTRIBUTION FOR ONE 805 MHz CRYOMODULE

(12 total)



WAVEGUIDE TUNER OPTION

RF Fanout at Each Cavity



KLYSTRON
- RF Power Source
- Located in Gallery above tunnel
- Each Klystron Feeds 8-16 Cavities

DIRECTIONAL COUPLER
- Picks of a fixed amount of RF power at each station
- Passes remaining power downstream to other cavities

CIRCULATOR / ISOLATOR
- Passes RF power forward towards cavity
- Diverts reflected power to water cooled load

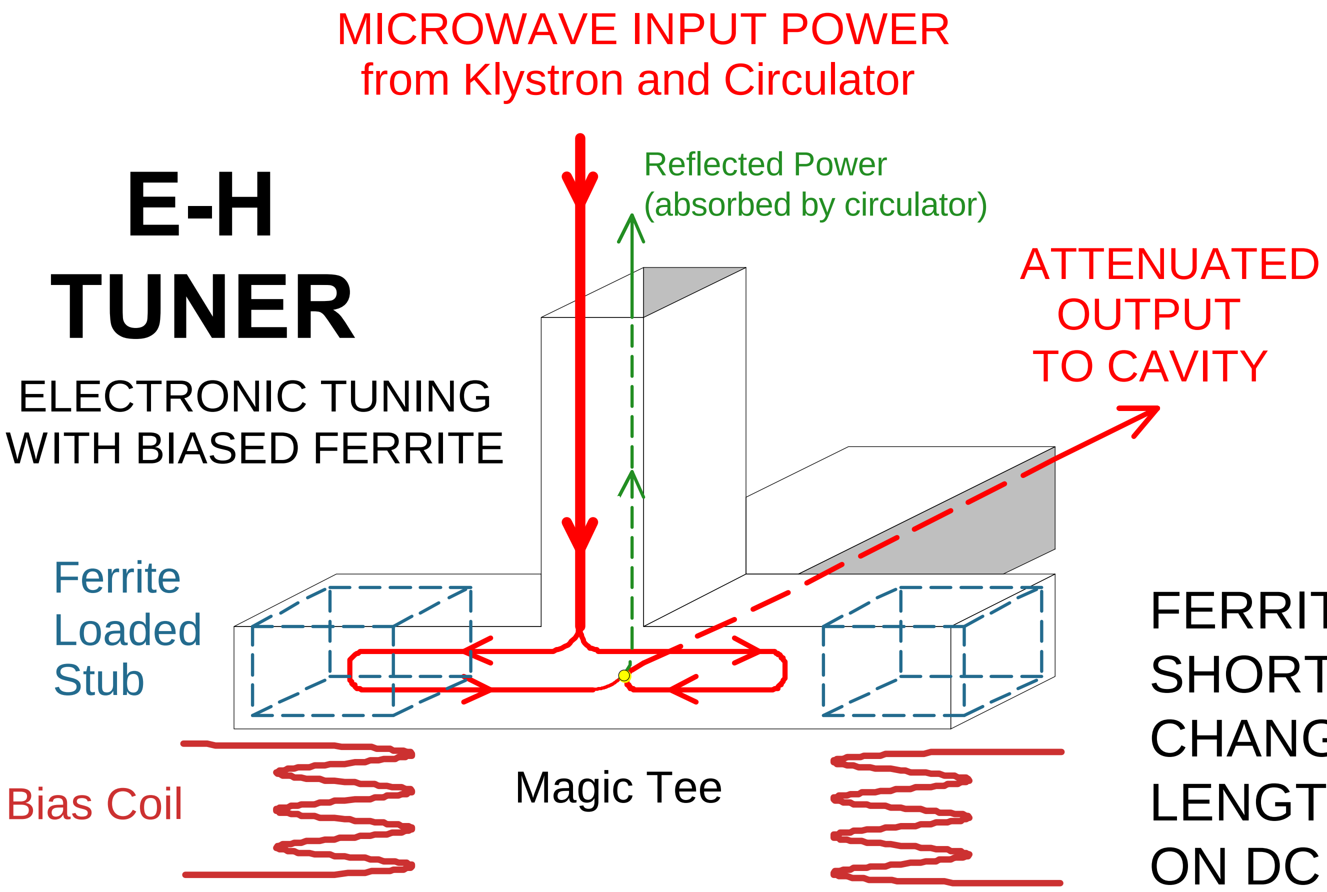
E-H TUNER
- Provides Phase and Amplitude Control for Cavities
- Biased Ferrite Provides Electronic Control

SUPERCONDUCTING RF CAVITY
- Couples RF Power to Beam

Fast Ferrite Phase Shifter R&D

- Needed to provide fast, flexible drive to individual cavites of a proton linac, when one is using TESLA-style RF fanout.
- Also needed if Linac alternates between e and P.
- The fundamental technology was proven in phased-array radar transmitters in ~1960.
- This R&D was started by SNS but dropped due to lack of time. They went to one-klystron-per-cavity which cost them a lot of money (~$20M).

ELECTRONICALLY ADJUSTABLE E-H TUNER



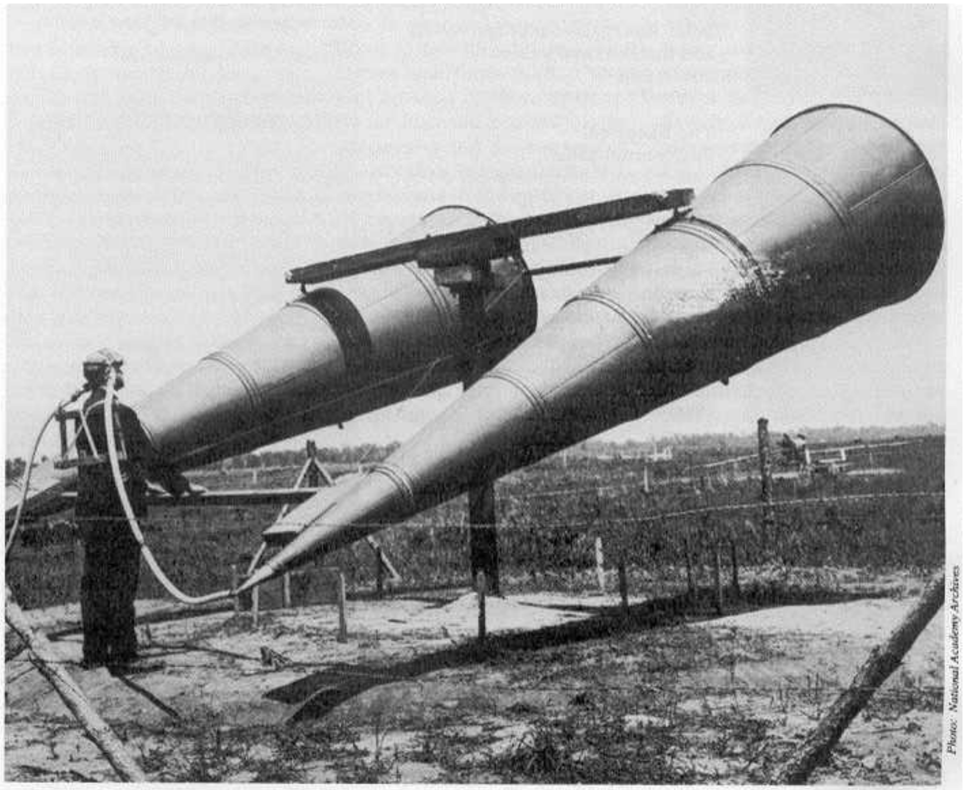
Attractive Price Quote from AFT

(<< Klystron)

FERRITE LOADED SHORTED STUBS CHANGE ELECTRICAL LENGTH DEPENDING ON DC MAGNETIC BIAS.

TWO COILS PROVIDE INDEPENDENT ***PHASE AND AMPLITUDE*** CONTROL OF CAVITIES

CAVITY MICROPHONICS



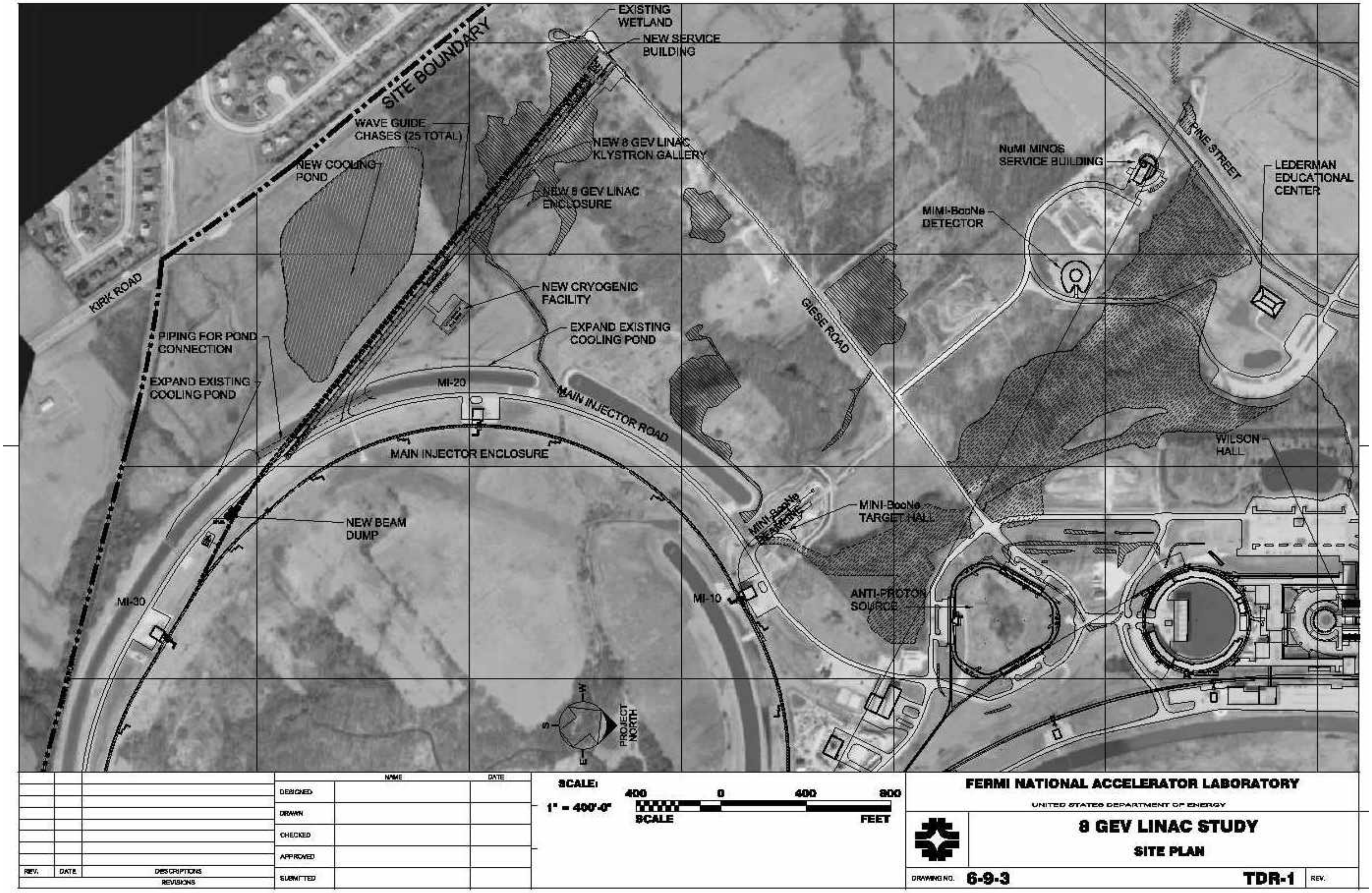
World War I Aircraft Detection

Within days of U.S. entry into World War I in April 1917, the Navy requested the National Research Council's help in developing a method for detecting and locating aircraft. The Research Council passed the problem along to George W. Stewart, head of the physics department at the State University of Iowa. After some experimentation, Stewart designed a set of 18-foot-long listening horns, which were supposed to provide anti-aircraft and searchlight batteries with early warning of distant enemy aircraft. Stewart's device never made it past the experimental stage; for field use, the American Expeditionary Forces adapted an aircraft sound locator purchased from the French. This photo shows a set of these horns undergoing trials at Ellington Field, outside of Houston, Texas, in Spring 1918.

96 ISSUES IN SCIENCE AND TECHNOLOGY

- Cavity Bandwidths are ~ 1 kHz (Q~10^6)
- Mechanical vibrations can shift resonant freq. by comparable amount.
- Produces large shift in required *phase* and *amplitude* of RF drive
- This drives control & bandwidth requirements of ferrite tuners

8 GeV Linac - Siting for Design Study (FESS)



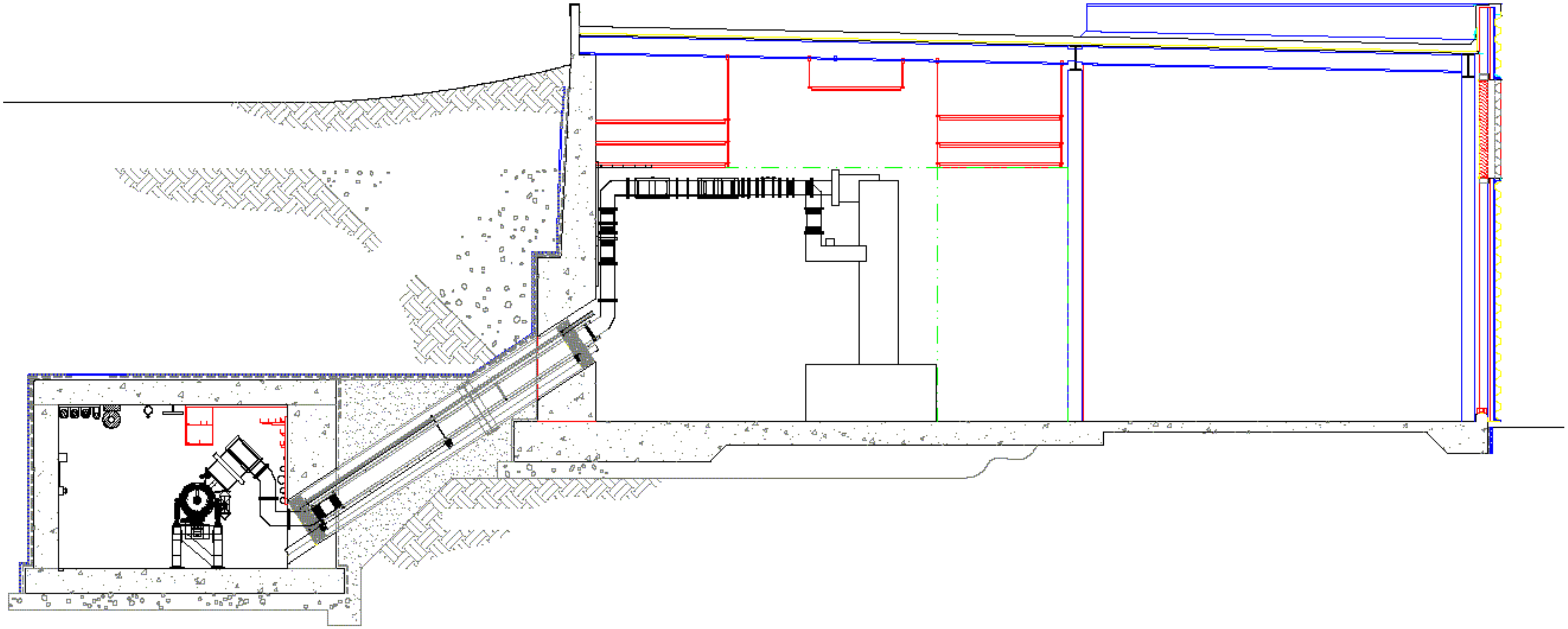
TUNNEL AND GALLERY

- Dual-Tunnel Configuration Chosen
- More expensive than surface gallery
- Fewer Radiation Issues
- Temperature Stability Better
- Simple Layout of Klystron tunnnel
  due to ~20m spacing between Klystrons
- Tunnel Buried to same depth as Main Injector
- Can use Main Injector Tunnel Cost Basis

SNS Tunnel & Klystron Gallery

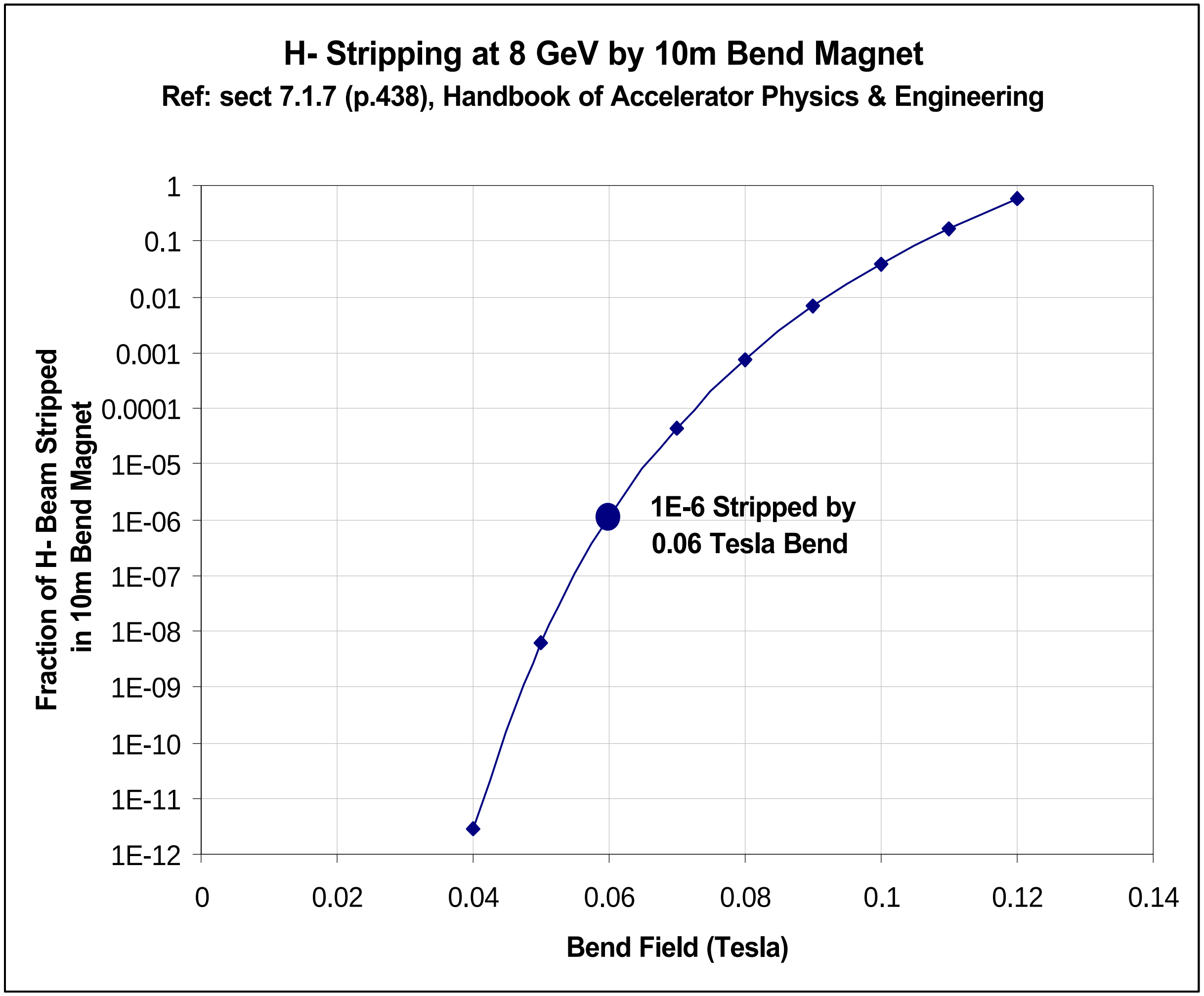
8 GeV Injector

Linac



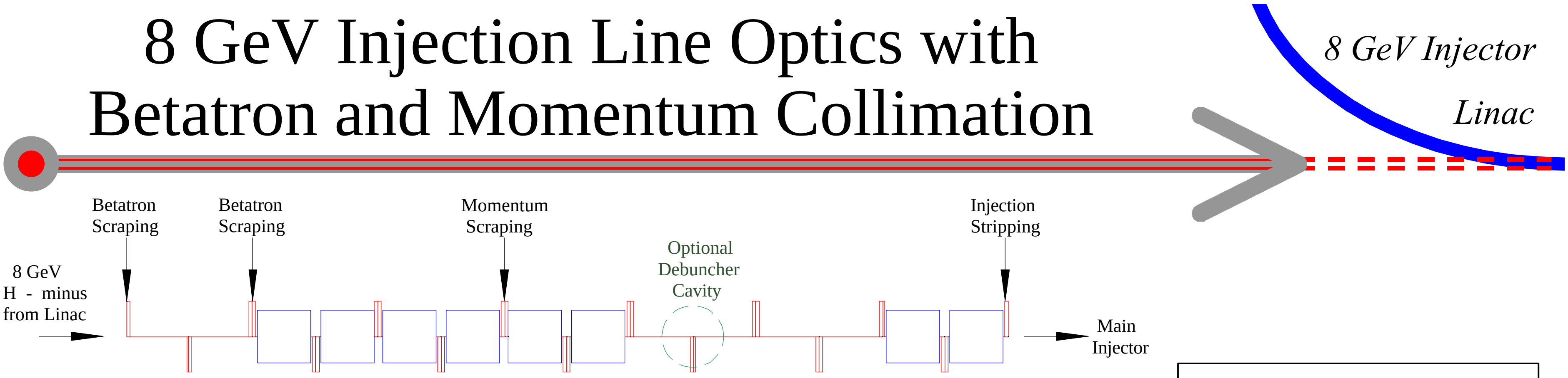
8 GeV H^- Stripping in Magnets

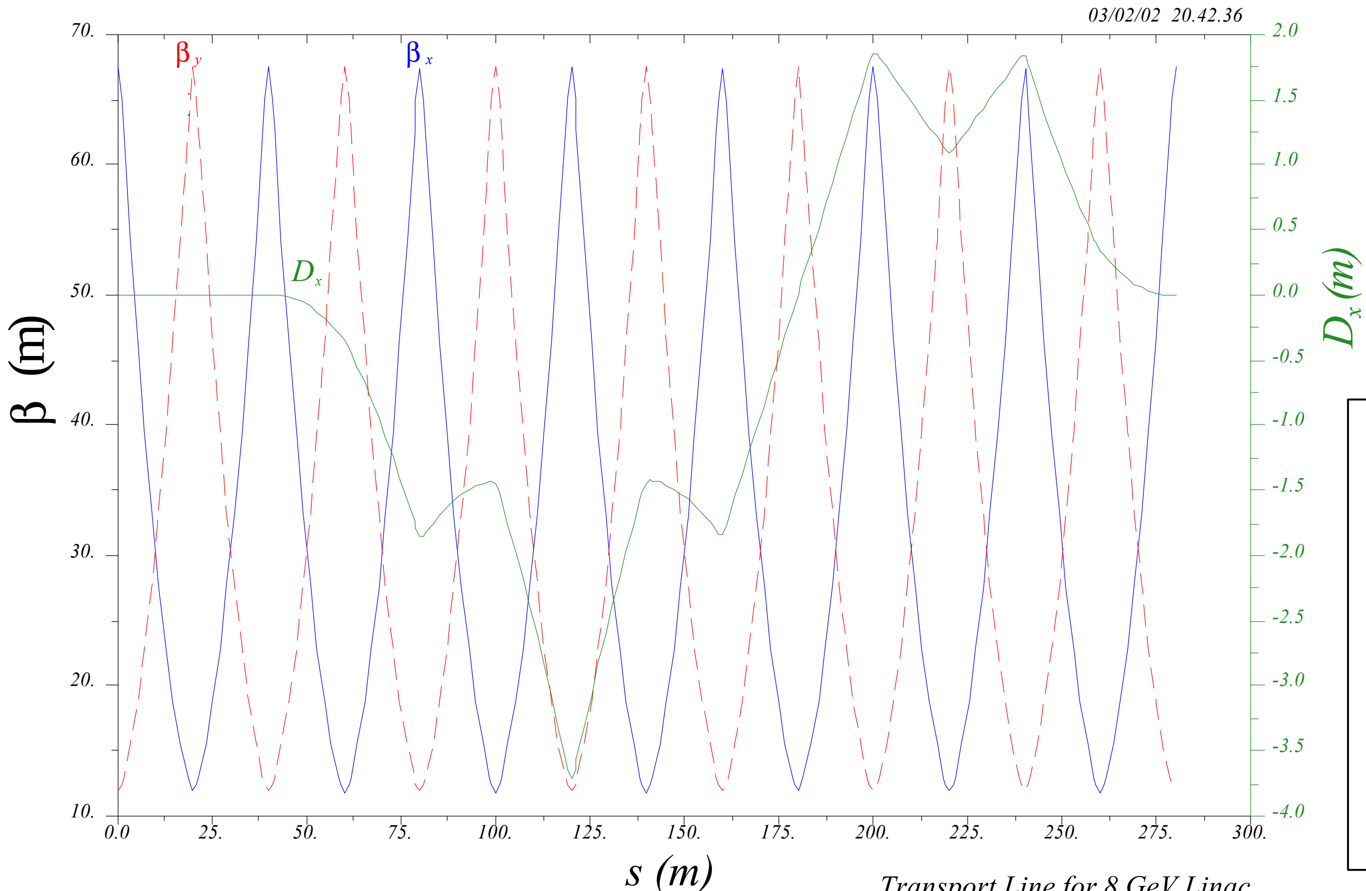
8 GeV Injector Linac



- B= 0.06 Tesla strips only 1E-6 of Beam in 10m length
- 500m Bend Radius is OK
- Stripped Beam Power is <1 Watt

8 GeV Injection Line Optics with Betatron and Momentum Collimation



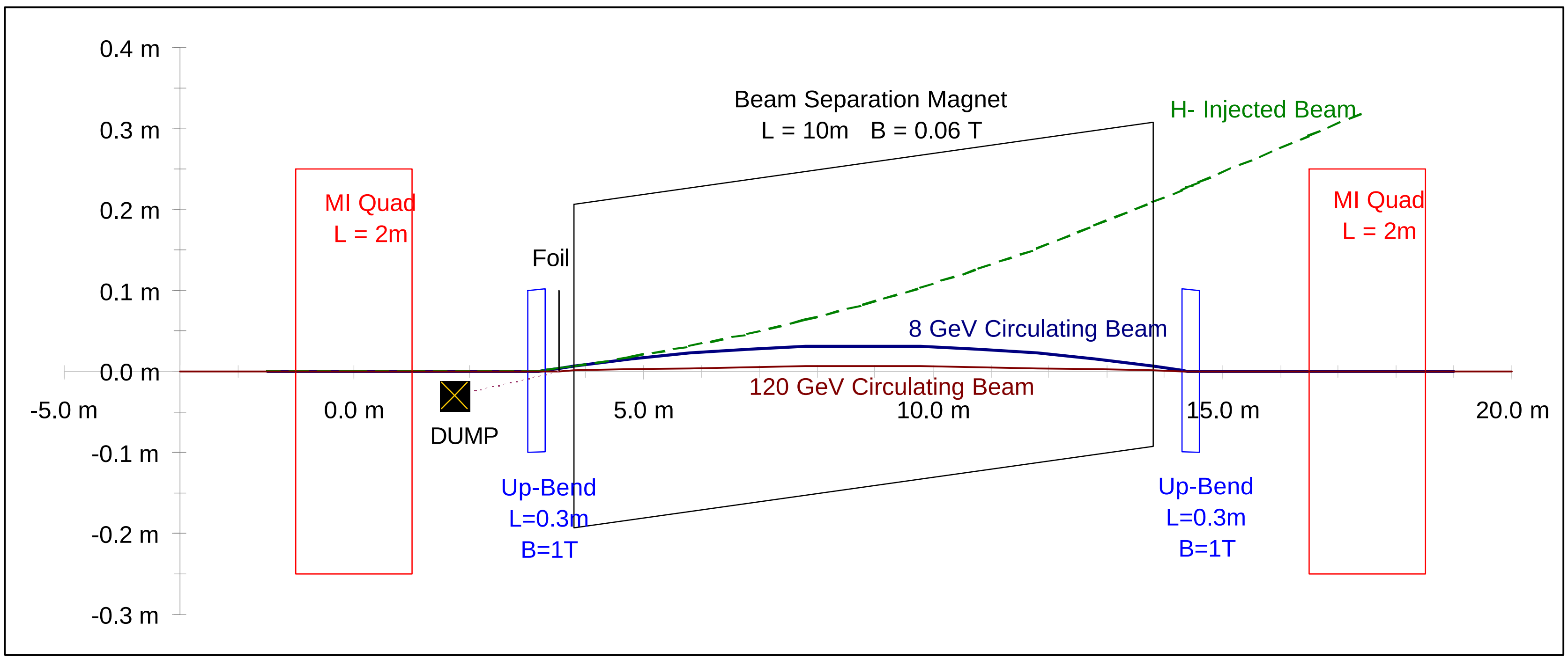


Similar to BNL Design for SNS

Ensures that no beam halo is delivered to ring

H⁻ Injection Layout in MI

- Foil Stripping Injection at 8 GeV
- Slow orbit bump disappears as beam accelerates
  (fast, smaller orbit bump also required to escape foil)
- Injected beam misses nearest quad in MI straight section



H- Injection Painting

(A. Drozhdin)

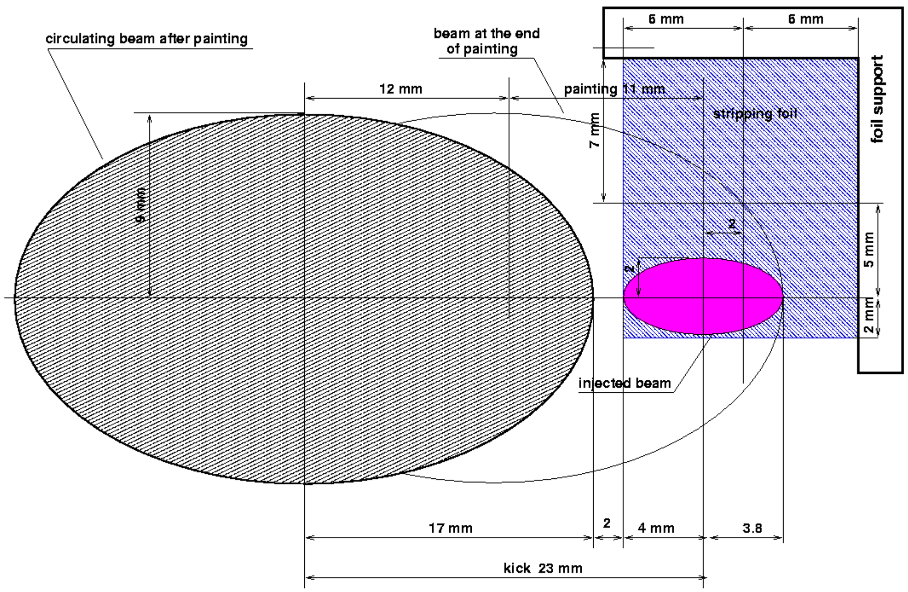
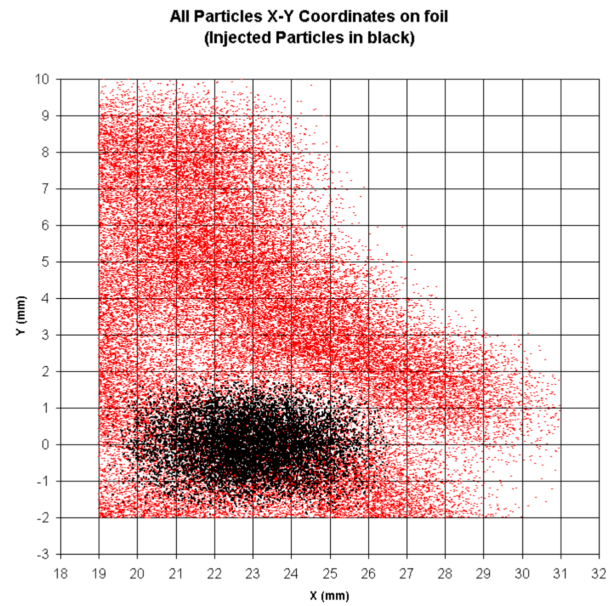
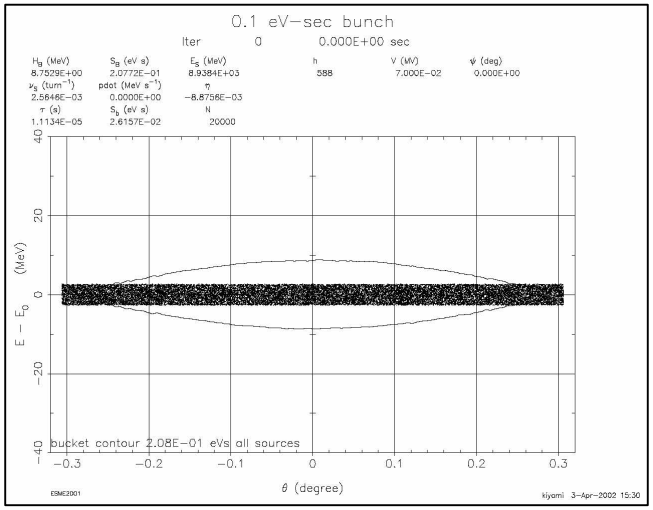


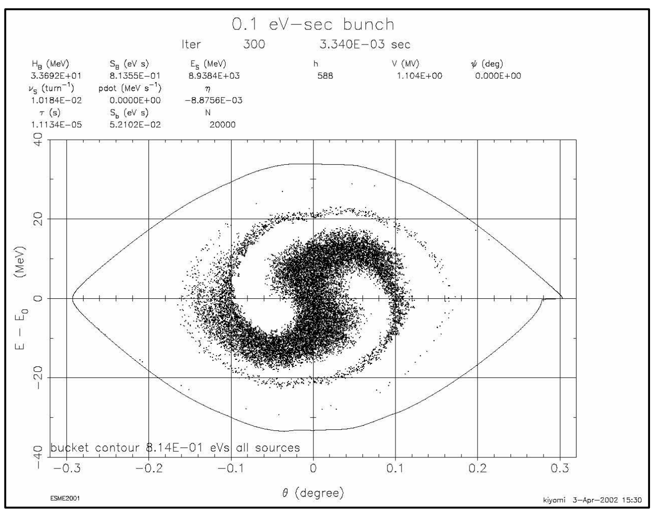
Figure 1: Injected and circulating beam location in the foil at painting.



- Painting from 2pi into 40pi with 90-turn injection seems feasible: (2-3 traversals/P)
- Peak foil temperature ~2200 degC (tolerable)

Adiabatic Capture vs. Chopping





- Adiabatic Capture at 8 GeV (no 53 MHz RF chopping)
- We are less sensitive to injection losses than SNS's (since $E_{INJECTION} << E_{FINAL}$)
- We have more time for Adiabatic Capture (100 ms)
- Simulations (K. Koba) indicate very high capture efficiency in shorter time.

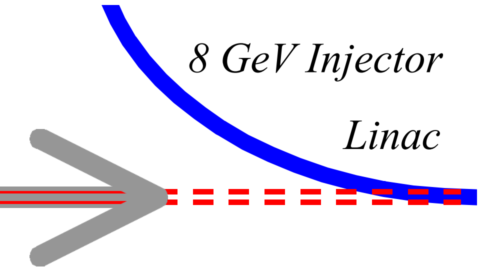
SECONDARY MISSIONS

- <u>Main Mission:</u> "Super-Beams" in Main Injector
- <u>Possible Secondary Missions:</u>
  1) 8 GeV Neutrino Program
  2) 8 GeV Spallation Neutron Source
  3) 8 GeV Fixed-target Program
  4) ν-factory front end (driver & muon acceleration)
  5) Electron Linac
  6) XFEL
  7) Recirculating microtron (pseudo-CEBAF)
  8) Pbar Deceleration
  9) TESLA damping ring preaccelerator linac …..

...etc... etc... etc...

Possible Secondary Mission #1:

8 GeV Neutrino Experiments



- 8 GeV beam for Mini-BooNE follow-on
- Interleave one 8 GeV cycle(s) with MI filling

  > 3.6E17 Protons/hr to *both* MI and BooNE
- Upgrade potential for >10 MW of 8 GeV beam
- ~ 20% efficiency wall power $\rightarrow$ beam
  - *Mini-BooNE confirms the LSND result, the 8 GeV linac could help increase statistics >20x.*

Possible Secondary Mission #3:

8 GeV Fixed-Target Program

8 GeV Injector

Linac

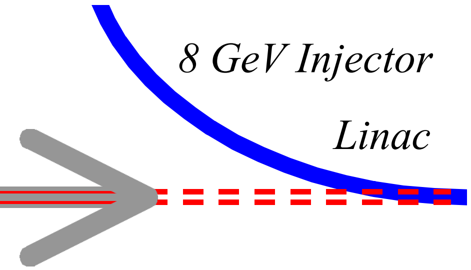
- Pion production per incident beam energy is maximized at ~6 GeV *(N. Mokhov)*

⇒ Best source for precision μ, K experiments.

- The RF time structure (~50 psec bunches) would allow high-quality TOF separation of neutral K's
- The Recycler might be used as 8 GeV stretcher ring to provide ~ continuous beams of protons.

Possible Secondary Mission #4:

Neutrino Factory

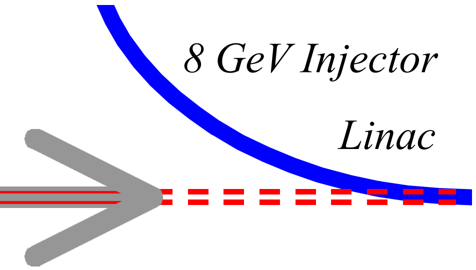


- Very Similar to 8 GeV Spallation Source
  (but shorter time spread on target)
- Possible to use *same linac* to *re-accelerate* the muons after filling the accumulator ring?
  1) use linac to fill the 8 GeV accumulator for ~1 msec.
  2) rephase the cavities for muon acceleration (~0.2 ms).
  3) bunch the accumulator beam and extract onto target.
  4) debunch & cool the muons in couple μsec
  5) reaccelerate the muons in *same* linac at 8 GeV/turn.

  → *everything uses DC magnets.*

Possible Secondary Mission #5:

8 GeV Electron Linac



- At least 7 GeV of the linac can accelerate e^-
  - electrons run on-crest, so the gradient will be higher

    $\Rightarrow$ 9-10 GeV e-beams
- Re-phase the cavites for (multiple) pulses of electrons between proton injections to FMI.
  - Many possible physics missions, test beams, etc.
  - Smaller activation problems than proton beams
- 8-GeV Linac makes an excellent XFEL driver

Possible Secondary Mission #8:

Antiproton Deceleration

Scenario:

1) Electron-cool Antiproton Beams in Recycler

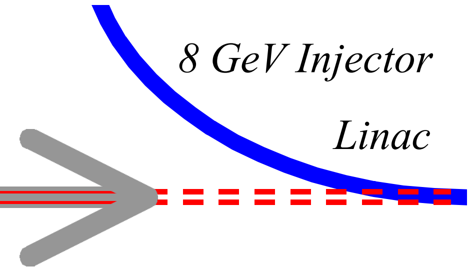
2) Ultra-cool core can be frictionally dragged away and separately extracted

3) Small emittances will decelerate efficiently in large-aperture SC Linac

$\Rightarrow$ World's best source of "stopped" antiprotons

Homework Assignment: does RF defocussing turn into RF focussing when decelerating P-bars?

VLHC and the 8 GeV Injector



- The small beam emittances obtainable with the 8 GeV Injector will make FNAL *by far* the best injector to a Very Large Hadron Collider (VLHC).
- Small Emittances ⇒ Small Beam Currents at fixed Luminosity
  - ⇒ Small Stored Energy in Beams
  - ⇒ Small instability problems in small beam pipes (⇒ Small magnets)

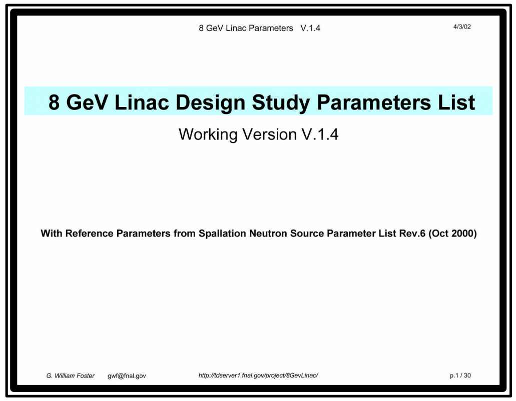
	Emittance	Luminosity	Beam Current	Stored Energy
VLHC Design Study	10 pi	1.00E+34	180 mA	2.8 GJ (8x LHC)
w/ 8 GeV Injector	0.5 pi	1.00E+34	40 mA	0.6 GJ (2x LHC)

Synchrotron vs. 8 GeV Linac

- There is little doubt that, in principle, a synchrotron is cheaper.
- If we are manpower limited: an 8 GeV Linac has many fewer parts to design than a new Booster Synchrotron.
- The 8 GeV linac will probably be simpler to operate.
- The 8 GeV linac will produce smaller emittances at low current, if that is the primary goal.
- It can accelerate electrons, and so has a broader range of uses.

Difficulty with reconciling Proton Driver with B&B subpanel recommendations can be finessed by 8 GeV Linac.

PROJECT INFORMATION


8 GeV Linac Parameters V.1.4 4/3/02

8 GeV Linac Design Study Parameters List

Working Version V.1.4

With Reference Parameters from Spallation Neutron Source Parameter List Rev.6 (Oct 2000)

G. William Foster gwf@fnal.gov http://tdserver1.fnal.gov/project/8GevLinac/ p.1 / 30

- 30 Page Parameter List (v1.4)
- (Soon) Cost Estimate Spread Sheet w/ BoE
- ~ May 15th - Design Study Final Report

http://tdserver1.fnal.gov/project/8GeVlinac

CONCLUSIONS

8 GeV Injector Linac

- An 8 GeV Injector Linac will be a useful component at FNAL no matter what future machine is built.
- There are no technical difficulties, just further optimizations. Can copy existing designs.
- It should make FNAL complex simpler to run.
- The cost could be similar to the Main Injector and Proton Driver.