# High Intensity Neutrino Source R&D

**Giorgio Apollinari**

**Fermilab, May 15th – 18th 2006**

# Talk Roadmap

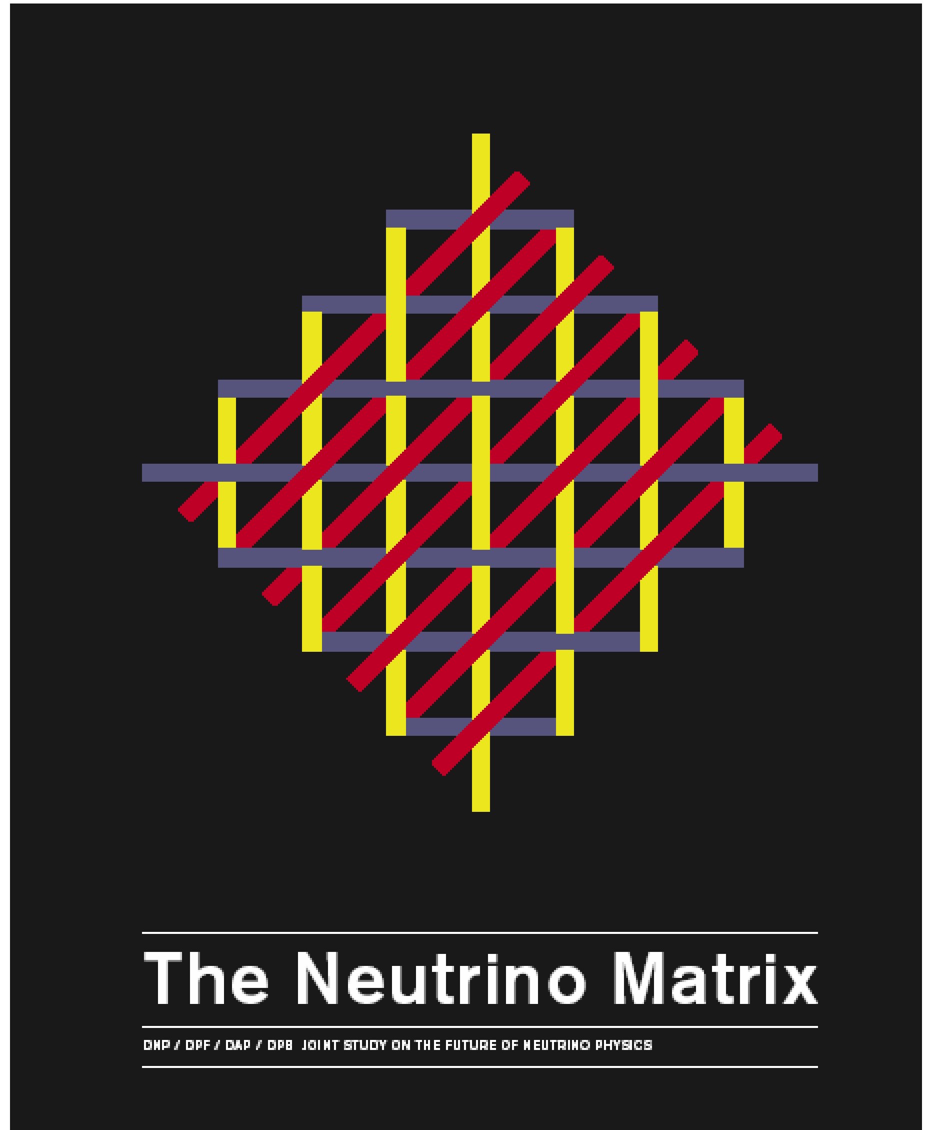
- **Charges to the Committee**
  - Scientific and technical merit and importance of the area
  - *(Feasibility for Carrying out the)* Proposed plans
  - Quality and impact of the recent research
  - Adequacy of the allocated resources
  - Comparison with other research groups engaged in similar activities
- **Introduction**
- **HINS Plans (2006-2010)**
- **Ongoing R&D Activities**
- **Resources: Funding & Manpower**
- **Synergies and Comparisons**

# Introduction - APS Neutrino Study

- **Interdivisional Study**
  - APS, DNP, DPF, DAP,..
- **Charges**
  - Examine broad sweep of ν physics
  - Create scientific roadmap for ν

WE RECOMMEND, AS A HIGH PRIORITY, A COMPREHENSIVE U.S. PROGRAM TO COMPLETE OUR UNDERSTANDING OF NEUTRINO MIXING, TO DETERMINE THE CHARACTER OF THE NEUTRINO MASS SPECTRUM, AND TO SEARCH FOR CP VIOLATION AMONG NEUTRINOS. THIS PROGRAM SHOULD HAVE THE FOLLOWING COMPONENTS:

- *An expeditiously deployed multidetector reactor experiment with sensitivity to $\bar{\nu}_e$ disappearance down to $\sin^2 2\theta_{13} = 0.01$, an order of magnitude below present limits.*
- *A timely accelerator experiment with comparable $\sin^2 2\theta_{13}$ sensitivity and sensitivity to the mass-hierarchy through matter effects.*
- *A proton driver in the megawatt class or above and neutrino superbeam with an appropriate very large detector capable of observing CP violation and measuring the neutrino mass-squared differences and mixing parameters with high precision.*



# Introduction – 8 GeV SC Linac

- **New* idea incorporating concepts from the ILC, the Spallation Neutron Source, RIA and APT.**
  - Copy SNS, RIA, and JPARC Linac design up to 1.3 GeV
  - Use ILC Cryomodules from 1.3 - 8 GeV
  - $H^-$ Injection at 8 GeV in Main Injector
- **"Super Beams" in Fermilab Main Injector:**
  - 2 MW Beam power at both 8 GeV and 120 GeV
  - Small emittances ==> Small losses in Main Injector
  - Minimum (1.5 sec) cycle time (or less)
  - MI Beam Power Independent of Beam Energy: *flexible program*

* *The 8 GeV Linac concept actually originated with Vinod Bharadwaj and Bob Noble in 1994,when it made no sense because the SCRF gradients weren't there. Revived and expanded by G.W.Foster in 2004*

# 8 GeV Superconducting Linac

# Two Design Points for 8 GeV Linac

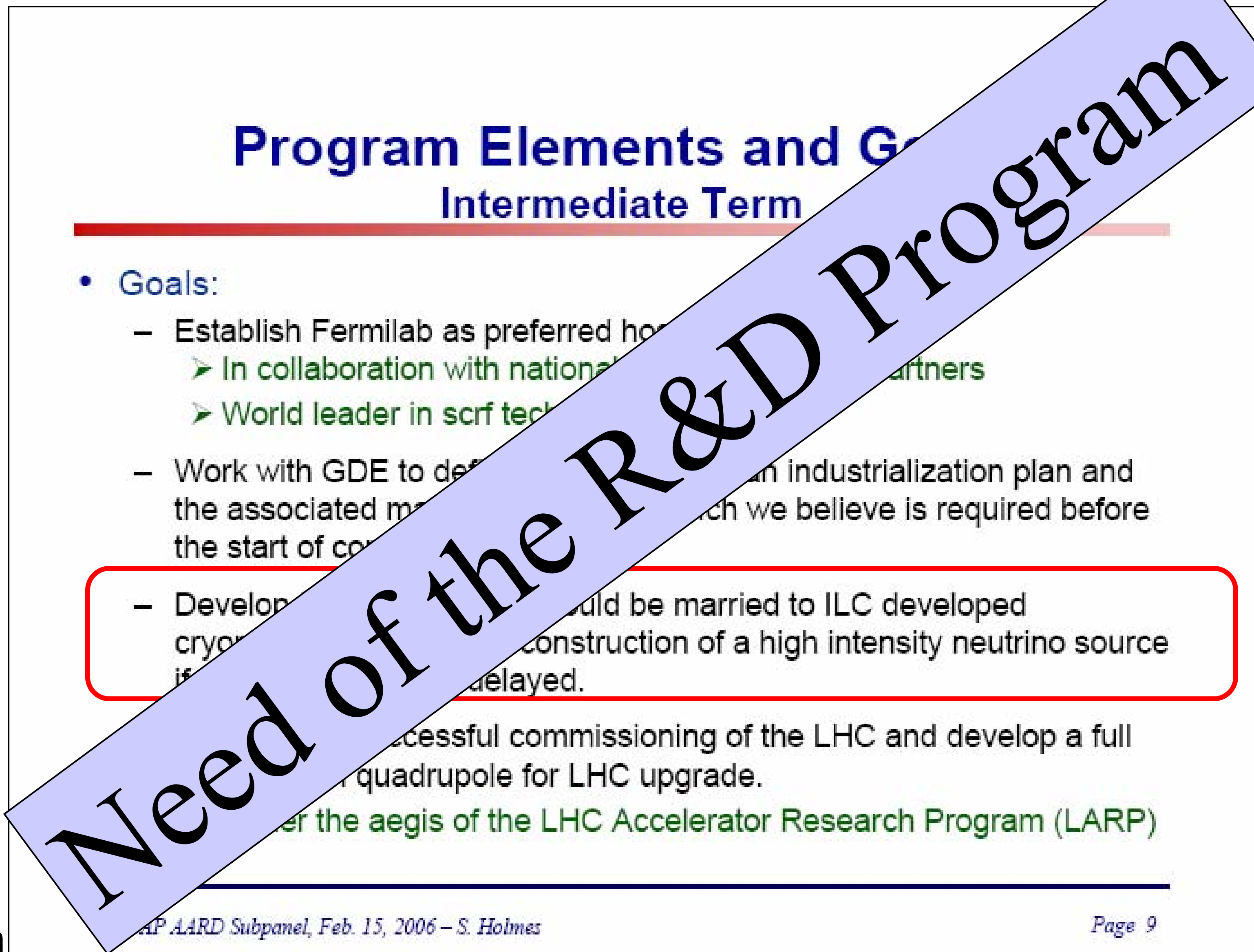
- **Initial: 0.5 MW Linac Beam Power (BASELINE)**
  - 8.3 mA x 3 msec x 2.5 Hz x 8 GeV = 0.5 MW
  - *11 Klystrons Required*
- **Ultimate: 2 MW Linac Beam Power**
  - 25 mA x 1 msec x 10 Hz x 8 GeV = 2.0 MW
  - *33 Klystrons Required*

***Either Option Supports:***

***1.5E14 x 0.7 Hz x 120 GeV***

***= 2 MW Beam Power from MI***

# Introduction:  ILC- HINS Interplay



## Program Elements and Go

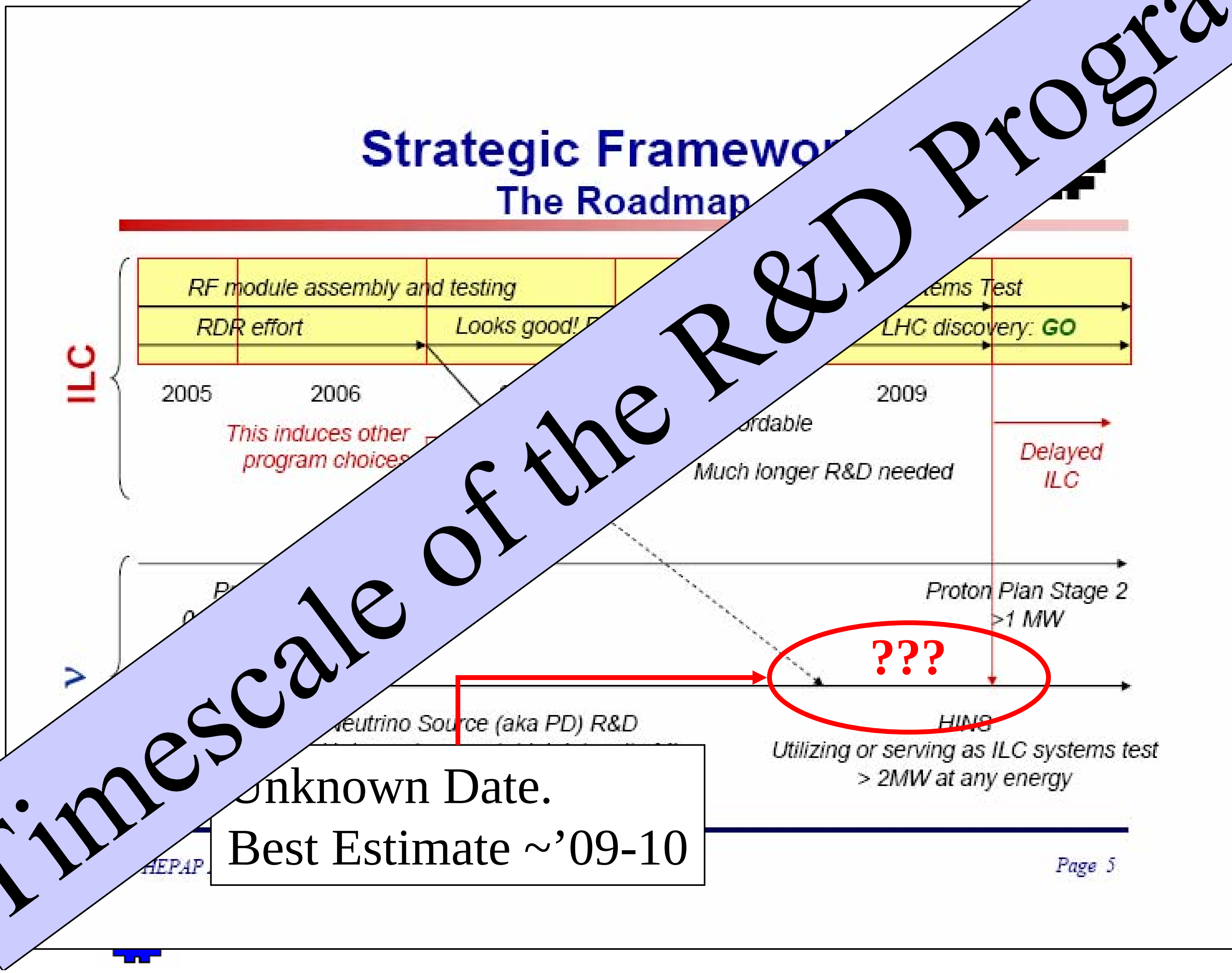
### Intermediate Term

- Goals:
  - Establish Fermilab as preferred ho
    - In collaboration with nationa ... rtners
    - World leader in scrf tec
  - Work with GDE to de ... n industrialization plan and the associated m ... ch we believe is required before the start of co
  - Develop ... uld be married to ILC developed cryo ... construction of a high intensity neutrino source if ... delayed.
  - ... ccessful commissioning of the LHC and develop a full ... quadrupole for LHC upgrade.
    - ... er the aegis of the LHC Accelerator Research Program (LARP)

AP AARD Subpanel, Feb. 15, 2006 – S. Holmes    Page 9

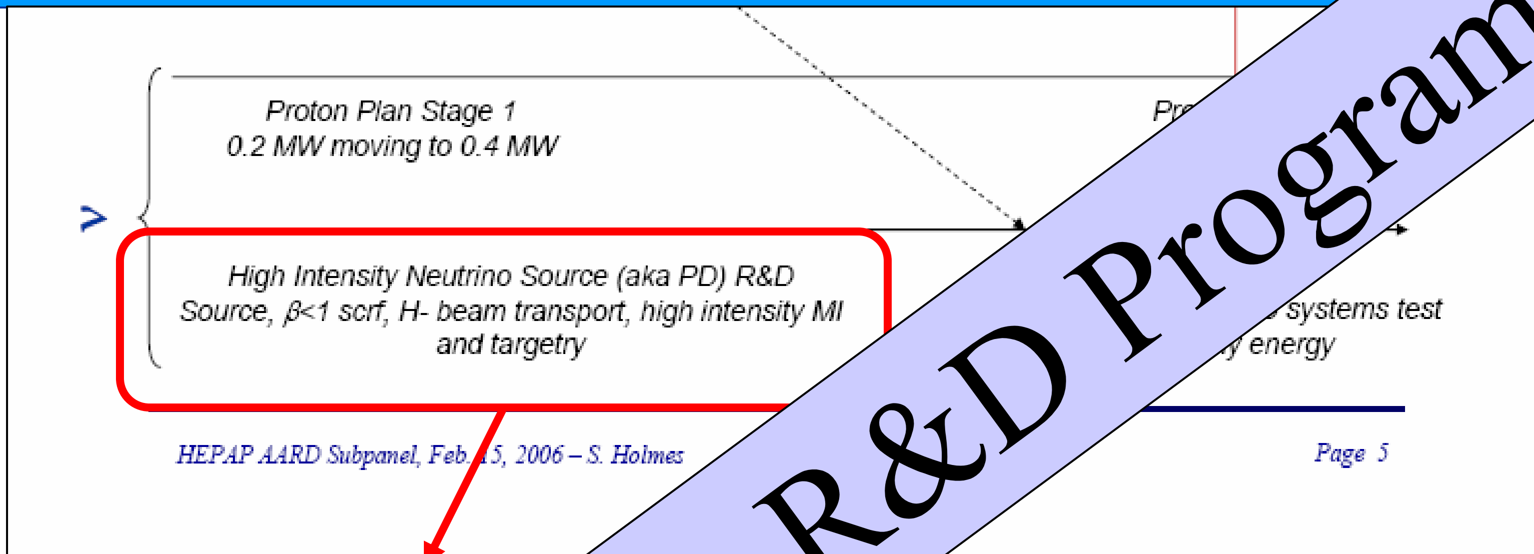
**Need of the R&D Program**

# Introduction: ILC-HINS Interplay



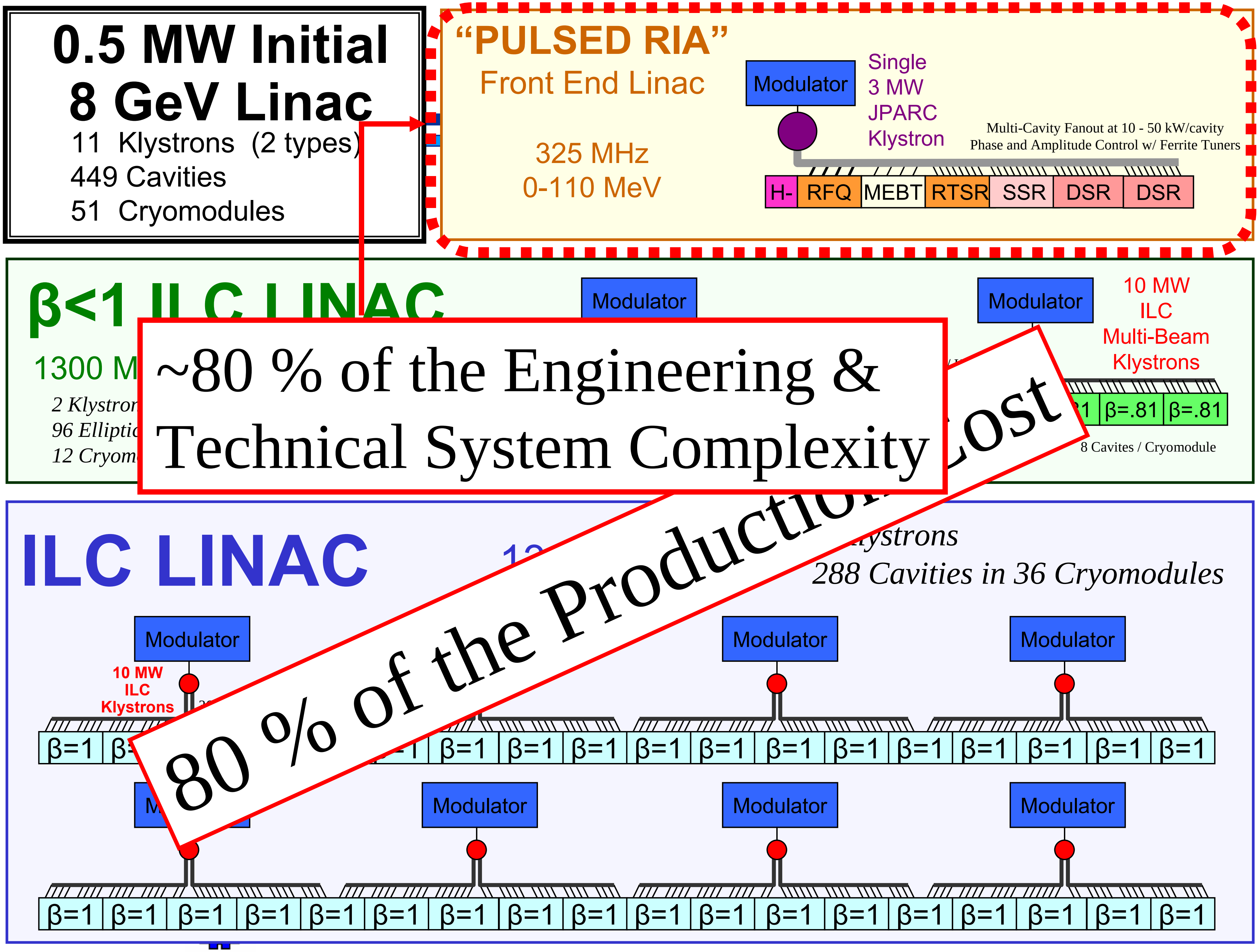

Timescale of the R&D Program

# Introduction: HINS Goals (2006-2009)




Goals of the R&D Program

- **Design fully ILC-Com**
- **Prove, Develop & … d in Meson Detector Bldg. (0-90 MeV)**
  - Much of Te… y in Front End Mechanical/RF Systems
    - Test … odulator and RF Power Scheme with $H^-$ *a world first !*
    - … on at 10 MeV *a world first !*
    - … ity to test/operate SC Spoke Cavities at FNAL
    - … Beam in the world through Spoke Cavities *a world first !*
    - … xis-Symmetric focusing and Beam Chopping
- **Design/Plan MI Injection Line & MI Upgrade**

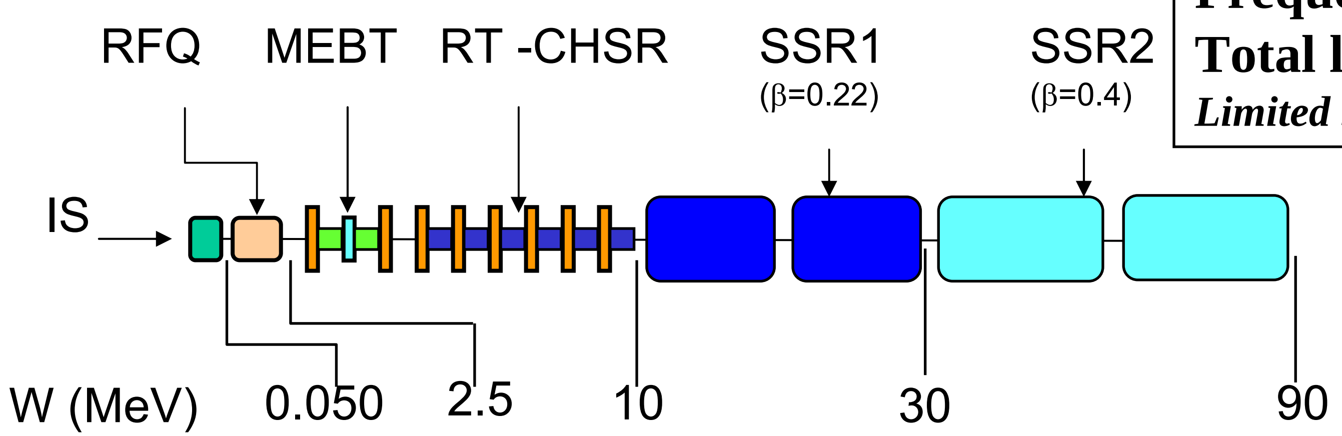


0.5 MW Initial
8 GeV Linac
11 Klystrons (2 types)
449 Cavities
51 Cryomodules
"PULSED RIA"
Front End Linac
325 MHz
0-110 MeV
Modulator
Single
3 MW
JPARC
Klystron
Multi-Cavity Fanout at 10 - 50 kW/cavity
Phase and Amplitude Control w/ Ferrite Tuners
H-
RFQ
MEBT
RTSR
SSR
DSR
DSR
β<1 ILC LINAC
1300 M
2 Klystron
96 Ellipti
12 Cryom
Modulator
Modulator
10 MW
ILC
Multi-Beam
Klystrons
β=.81
β=.81
8 Cavites / Cryomodule
~80 % of the Engineering &
Technical System Complexity
80 % of the Production Cost
ILC LINAC
288 Cavities in 36 Cryomodules
Modulator
10 MW
ILC
Klystrons
β=1

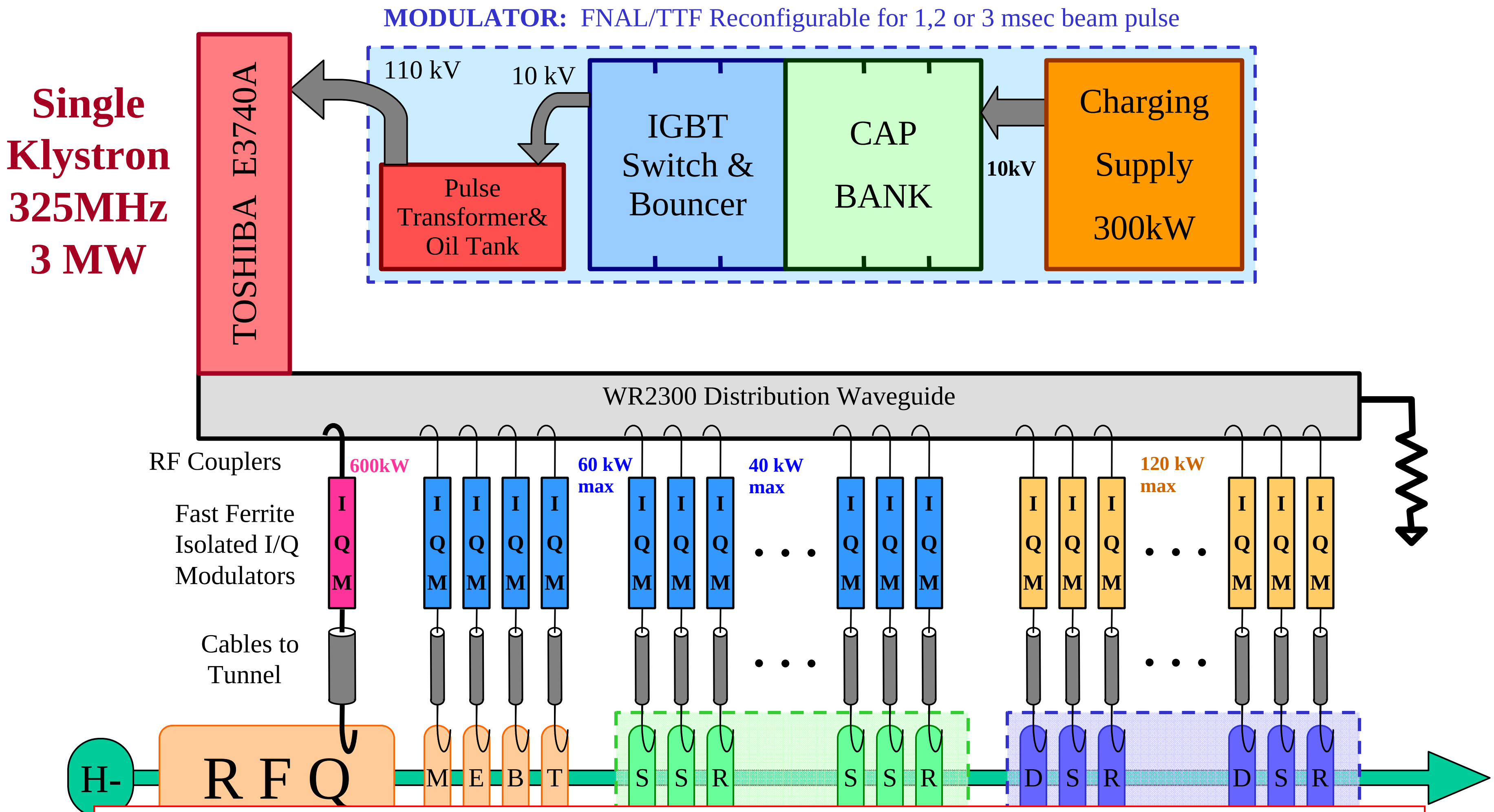
# Front End - Beam Line Layout

| | | | |
|---|---|---|---|
| **Ion source H$^-$, LEBT** | | | **50 keV** |
| **Radio Frequency Quadrupole** | | **4-5 m,** | **2.5 MeV** |
| **MEBT** | **(2 bunchers, 3 SC sol., chopper)** | **4 m** | |
| **RT TSR section** | **(16 resonators, 16 SC solenoid)** | **10 m** | **10 Mev** |
| **SSR1 section** | **(18 resonators, 18 SC solenoids)** | **14 m** | **30 MeV** |
| **SSR2 section** | **(22 resonators, 12 SC solenoids)** | **20 m** | **90 MeV** |

**Frequency 325 MHz**
**Total length ~ 55 m**
***Limited by Meson Building***

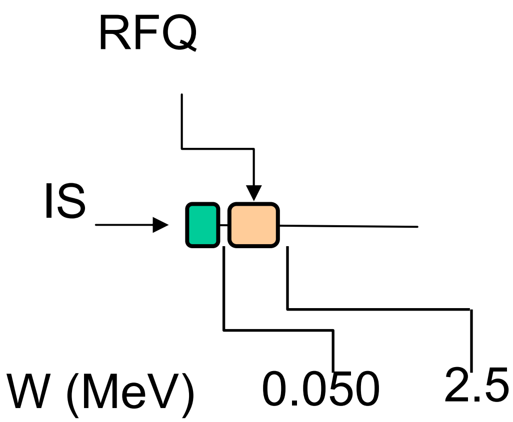


# Introduction: 325 MHz Front End




**The last two slides add up to building a one-of-a-kind superconducting 90 MeV $H^-$ linac**

# HINS Plans (2006-2009)

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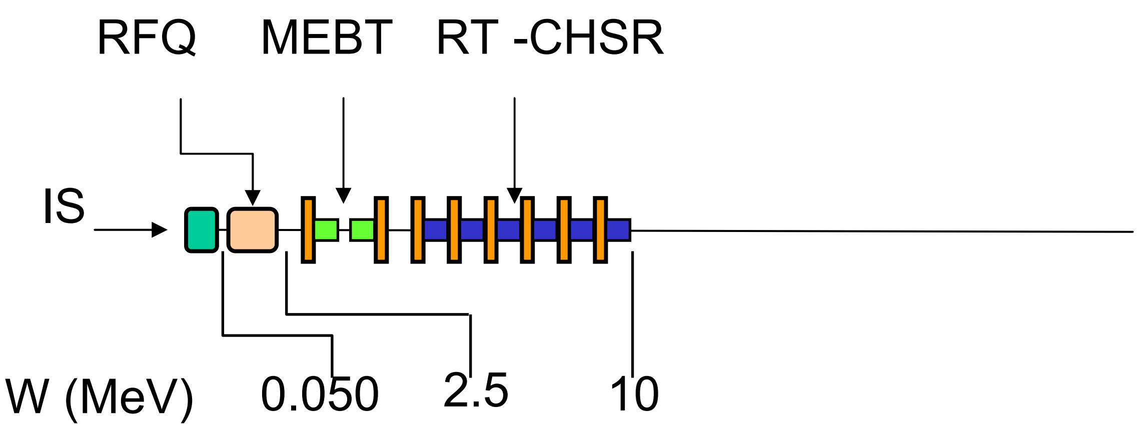
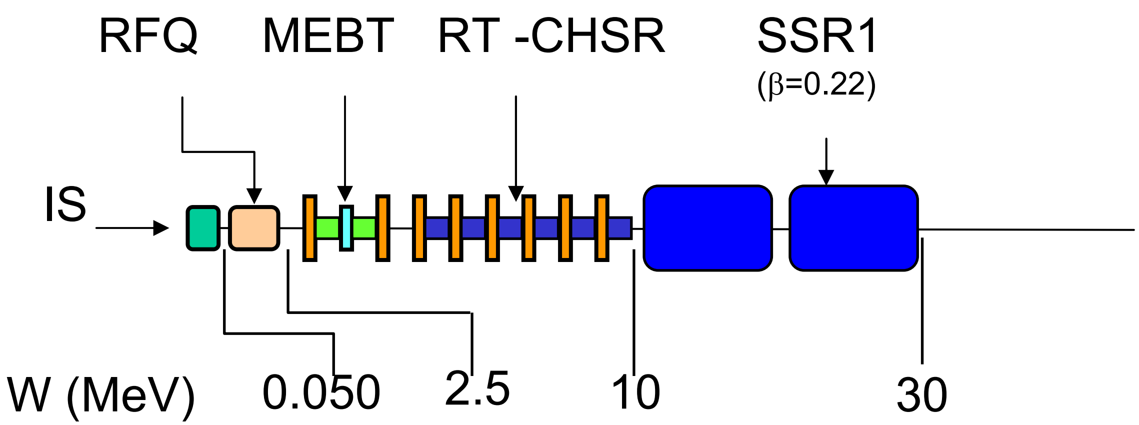
- **End FY06/Beg FY07**
  - Klystron/Modulator/Power Distribution
  - RFQ
  - Test Cryostat/Prototype SSR
  - Klystron & Power Distribution

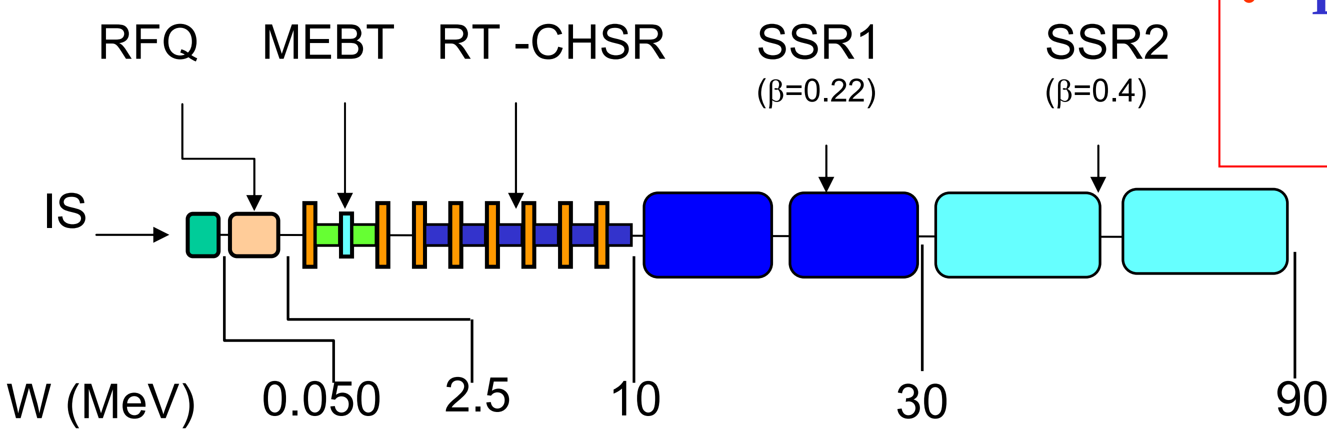



- **End FY07/Beg FY08**
  - RT Cavities
  - Focusing Solenoids
  - Buncher Cavities

# HINS Plans (2006-2009)




- **End FY08/Beg FY09**
  - 2 SSR1 cryostats
  - Chopper & PS
  - Linac Operation

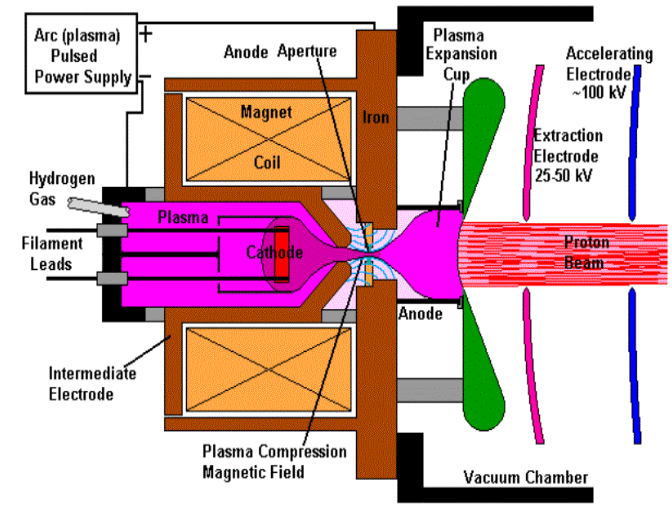



- **End FY09/Beg FY10**
  - 1 SSR2 cryostat
  - Linac Operation

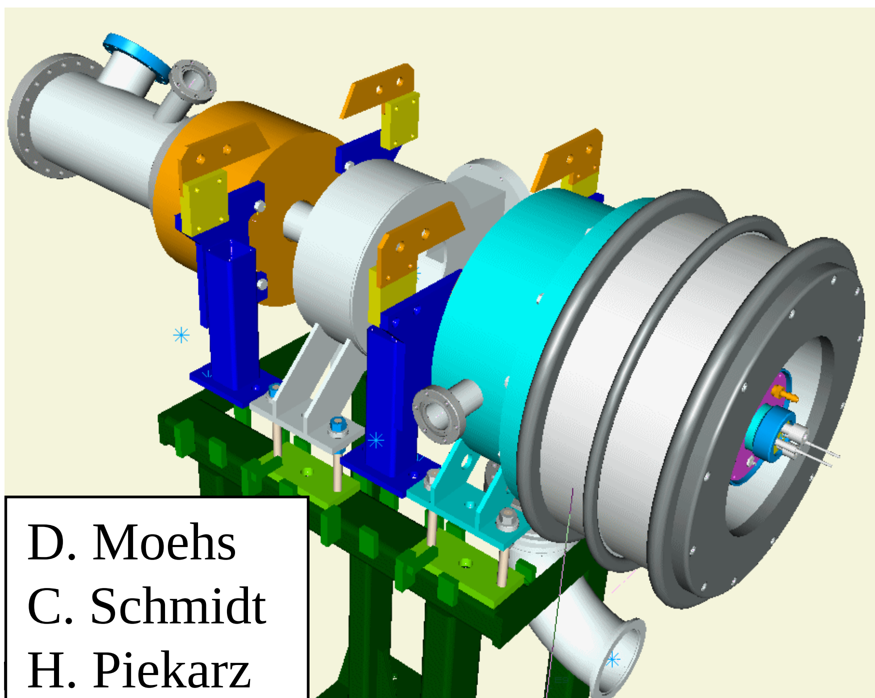
- ✓ **Introduction**
- ✓ **HINS Plans (2006-2010)**
- ❖ **Ongoing R&D Activities** ***(most intense)***
- **Resources: Funding & Manpower**
- **Synergies and Comparisons**

# Ongoing R&D Activities: Ion source

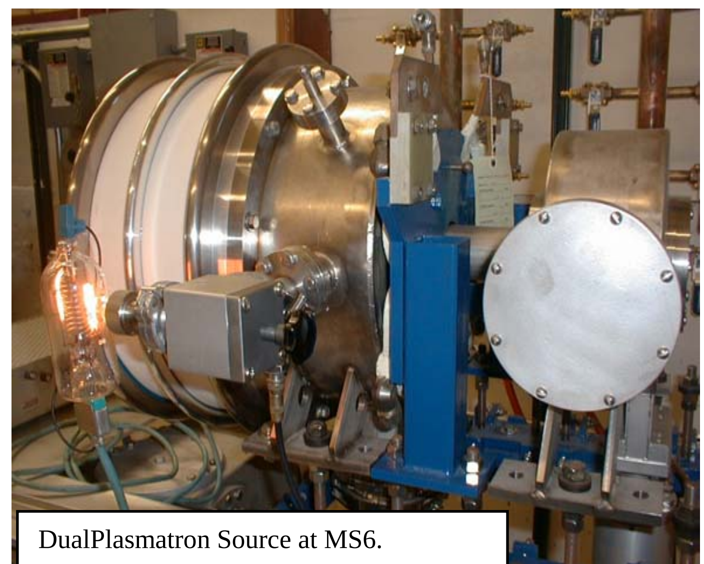
- **Plasmatron ($H^+$)**
  - Available and almost operational
- **Magnetron ($H^-$)**
  - Baseline, testing at BNL
  - Participating in Multicusp R&D




DUOPLASMATRON ION SOURCE

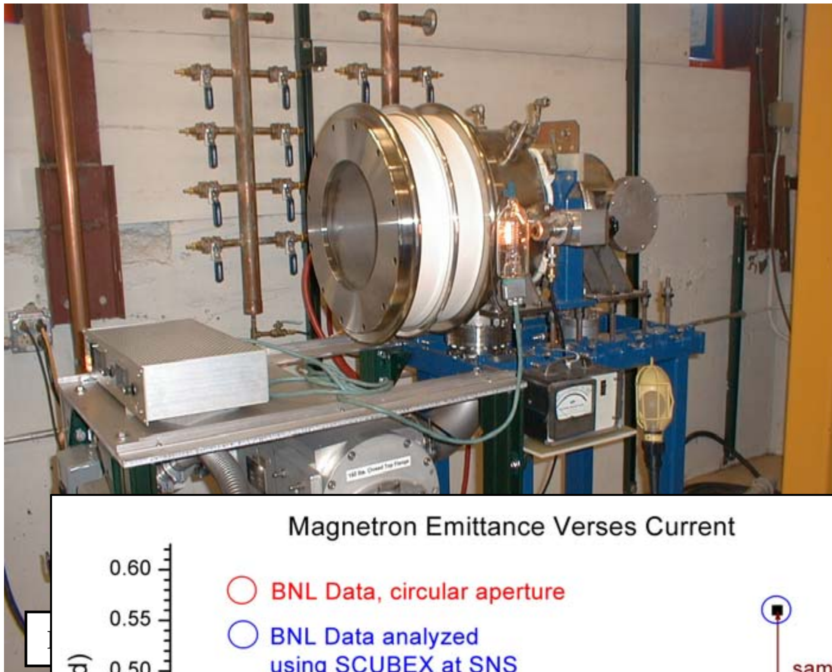


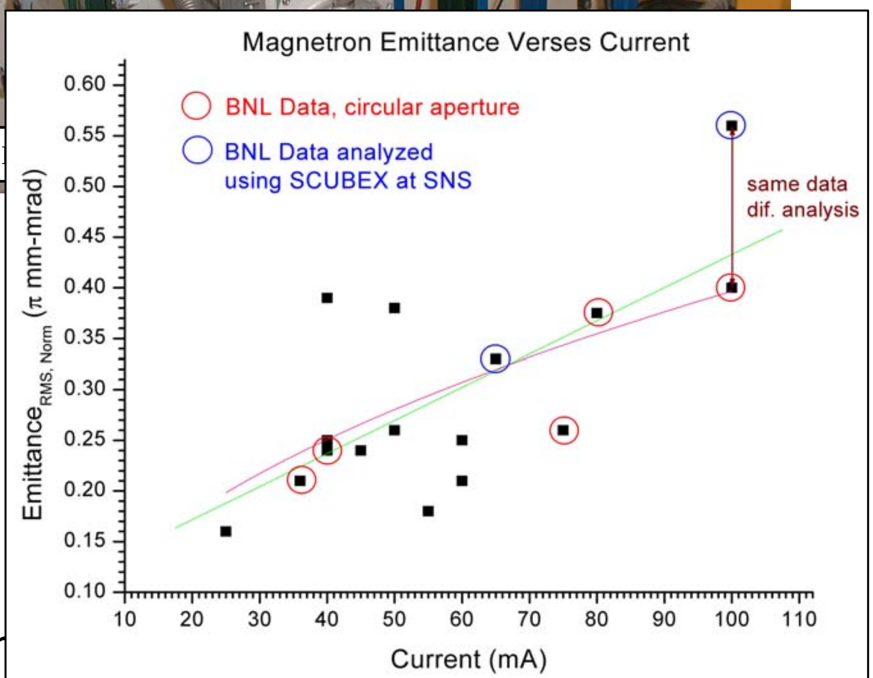
D. Moehs
C. Schmidt
H. Piekarz



DualPlasmatron Source at MS6.

# Ongoing R&D Activities: Ion source



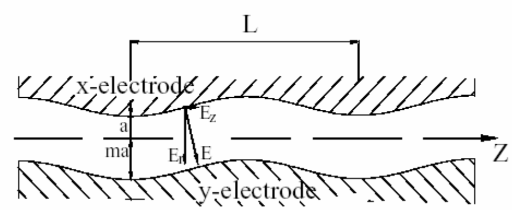


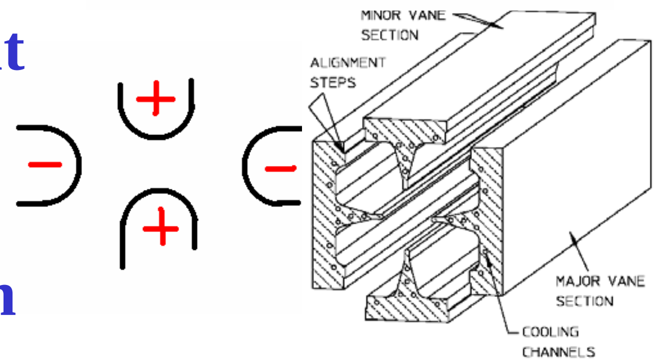



- **HV Tested to 75 kV**

# Ongoing R&D Activities: RFQ

- **RFQs are standard devices for proton machines (J-PARC, SNS).**
- **Our additional requirement for RFQ beam dynamics design is an axisymmetric output beam to reduce halo formation in MEBT and RT SR section.**
- **Beam-dynamics/Mechanical Collaboration between ANL & FNAL**



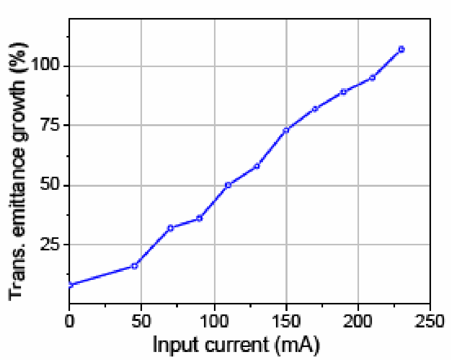




Figure 12. Transverse rms emittance growth factor in the cell #172.

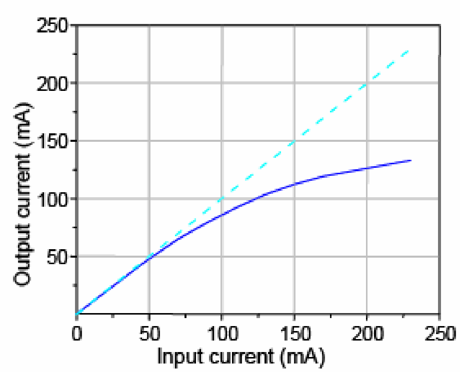



Figure 13. Transmission through the RFQ calculated for the same input transverse emittance.

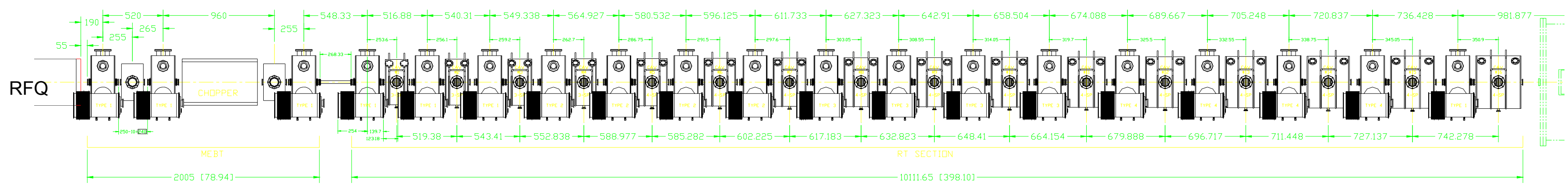
Figure 1 - The RFQ body

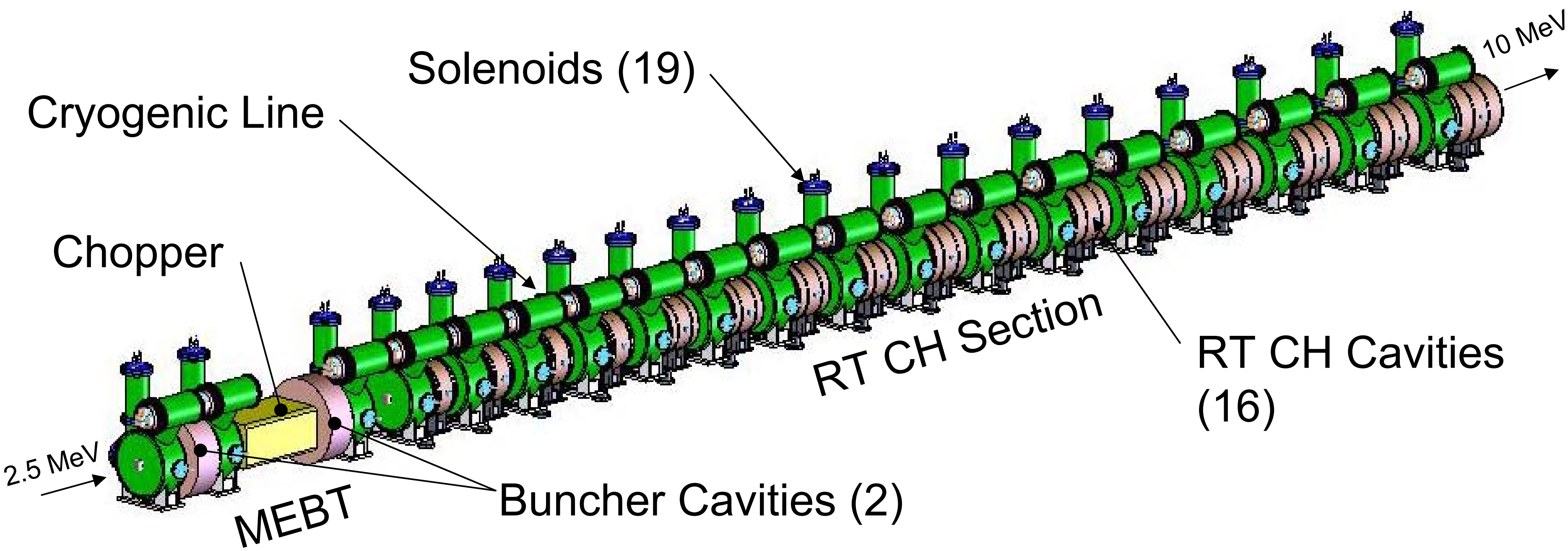
# RFQ R&D – Prototype Procurement

- **Quote requests were sent to several manufacturing companies in ~Sept. 05**
- **Fermilab received several quotes in the ~0.5 M$ range and production schedules ranging from 6-12 months.**
- **A 0.5 M$ requisition was placed in Jan ’06 and 3 bids were returned in March 06.**
  - Companies had the option to adopt ANL/FNAL design or propose their own design meeting FNAL Beam specs.
  - Vacuum Chambers and Power Couplers were included in the order
  - Companies were also requested to provide quote for commissioning support
- **Final vendor selection: May ’06.**
- **Expected delivery to Meson area in 6 months (~Dec. ’06)**
- **Installation and testing ~Jan. 07**

# MEBT & RT CH Sections

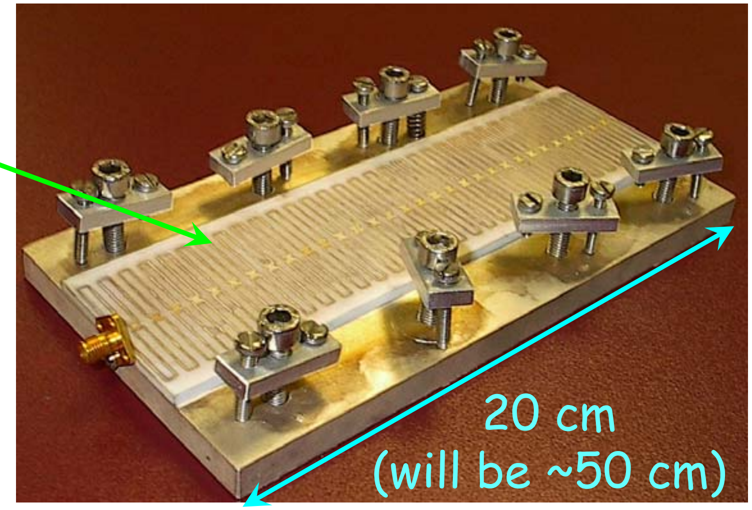
Top View

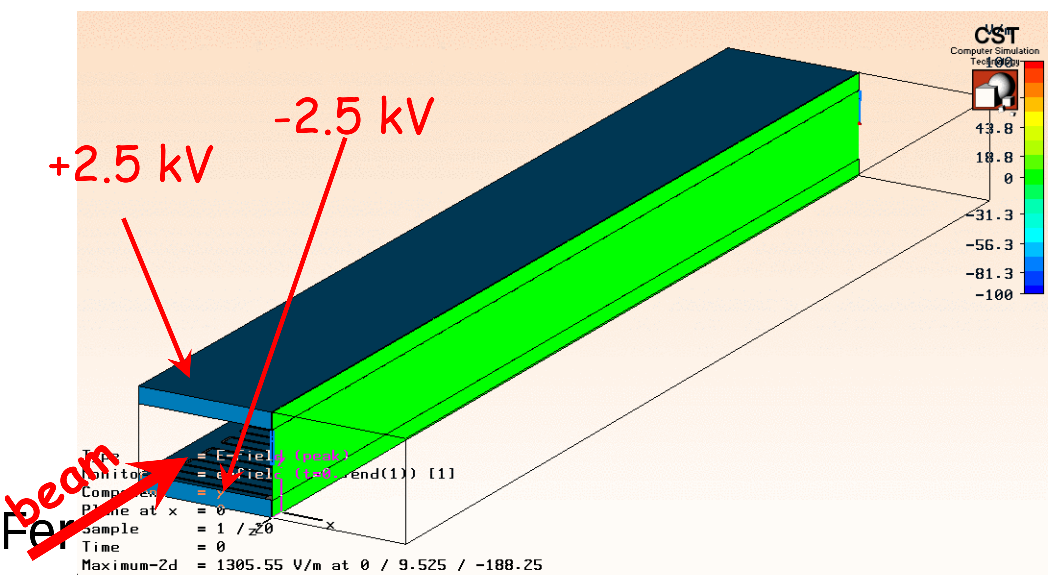


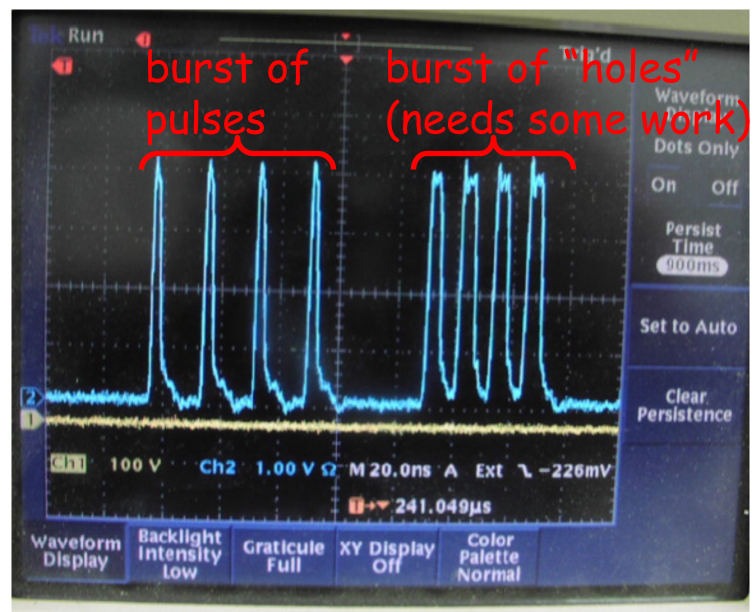



# MEBT & Chopper

- **Prototype meander from Fritz Kaspers (CERN):**
  - 50 Ω, MoMn/Ti/Ag on alumina substrate
- **We will need two meanders & two pulsers**
  - Rise and fall time <= 2ns
  - 53 MHz rep rate, burst of 3ms (1ms)
  - Programmable pulse width
  - R.Madrak, D. Wildman (FNAL)

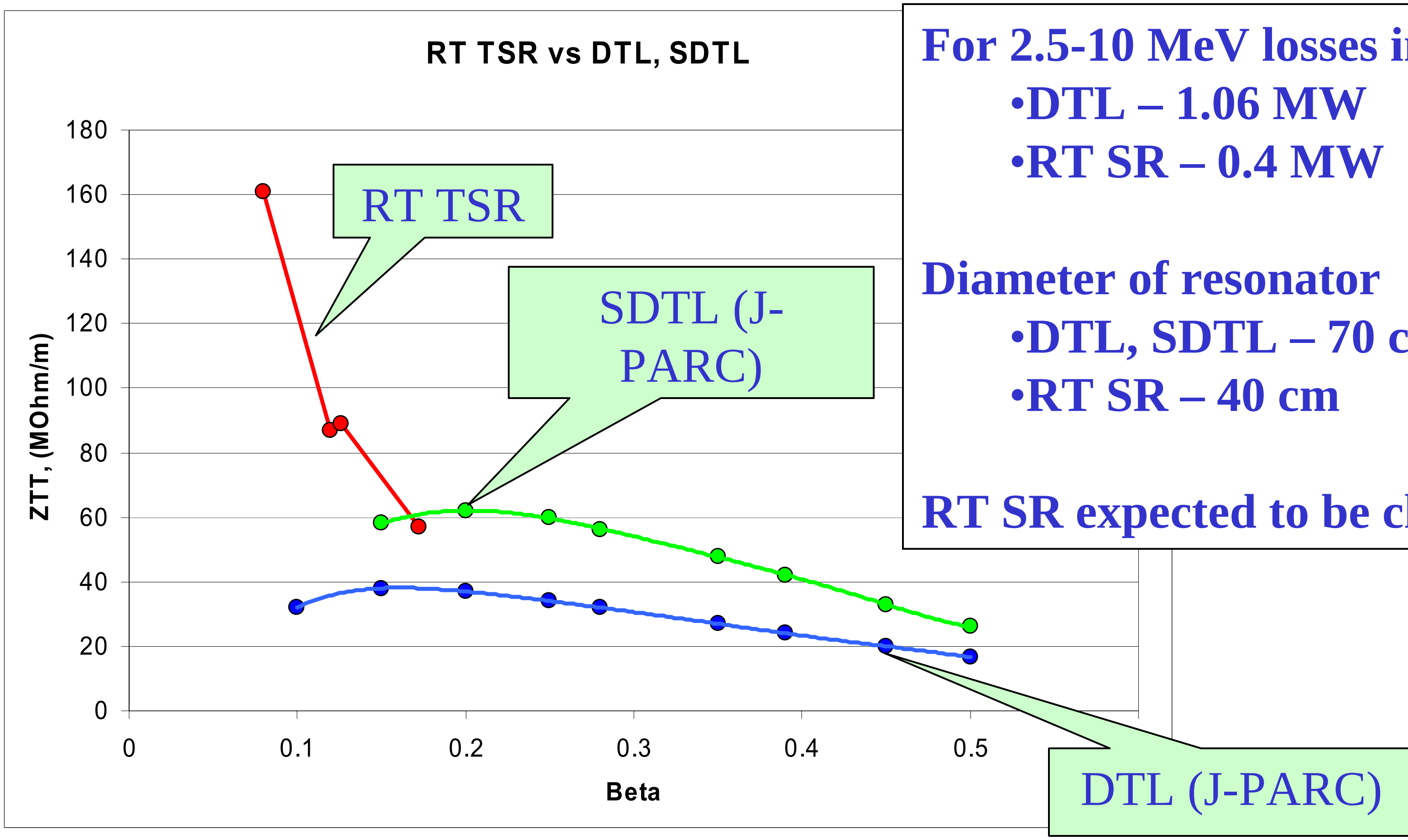


# RT SR section R&D (1)

**The main advantage of RT SR is its high shunt impedance.**

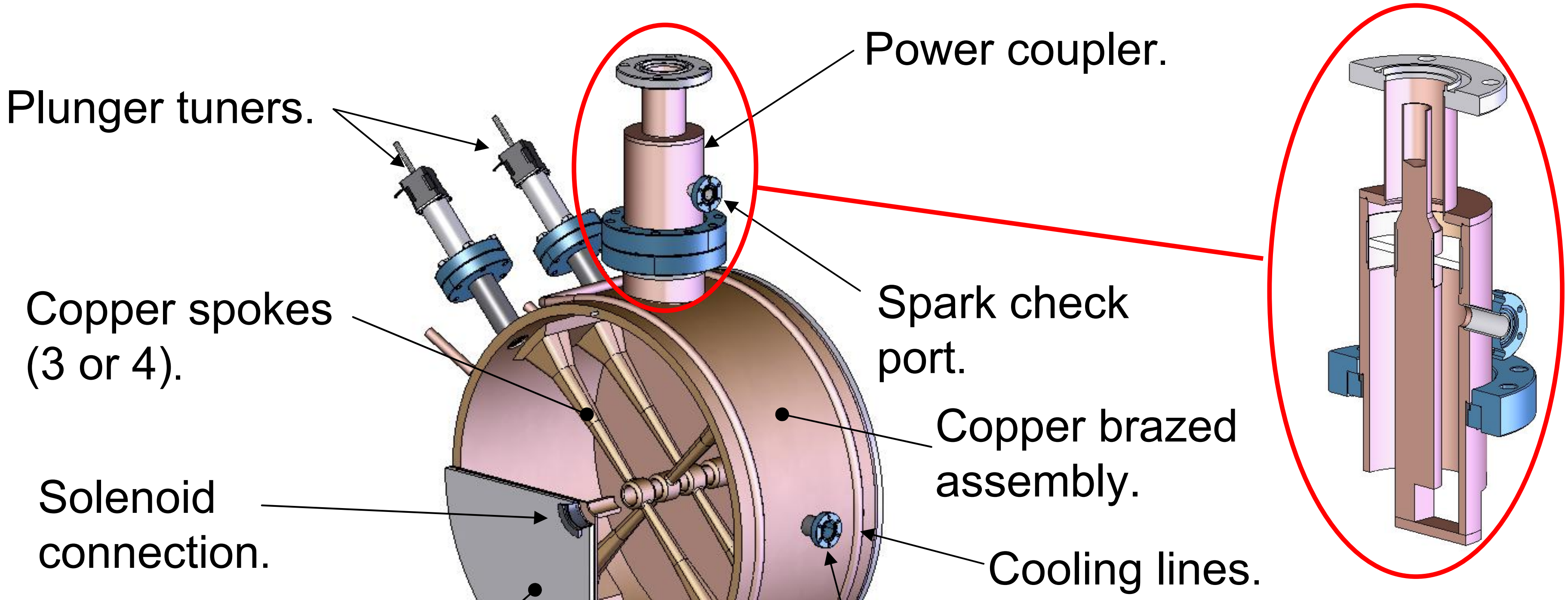


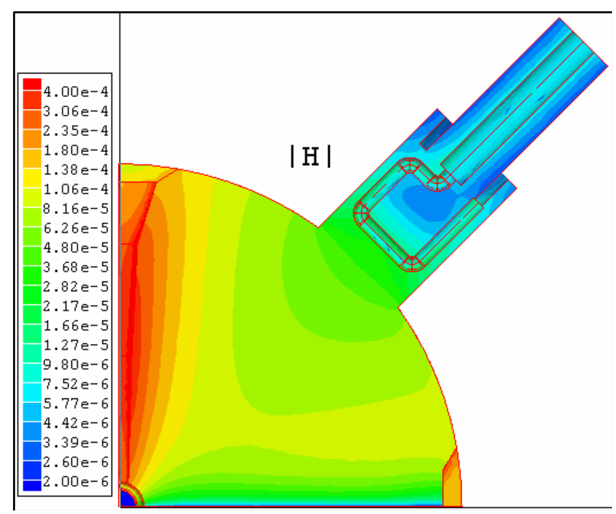

**For 2.5-10 MeV losses in copper:**
- **DTL – 1.06 MW**
- **RT SR – 0.4 MW**

**Diameter of resonator**
- **DTL, SDTL – 70 cm**
- **RT SR – 40 cm**

**RT SR expected to be cheaper**

# RT CH Cavity Details




G. Romanov
L. Ristori
I. Gonin

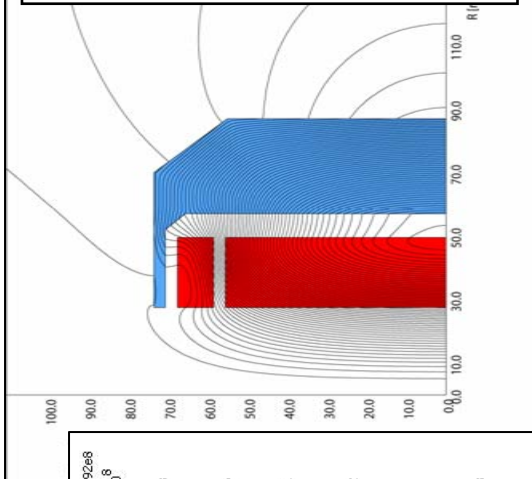
Prototype under Procurement

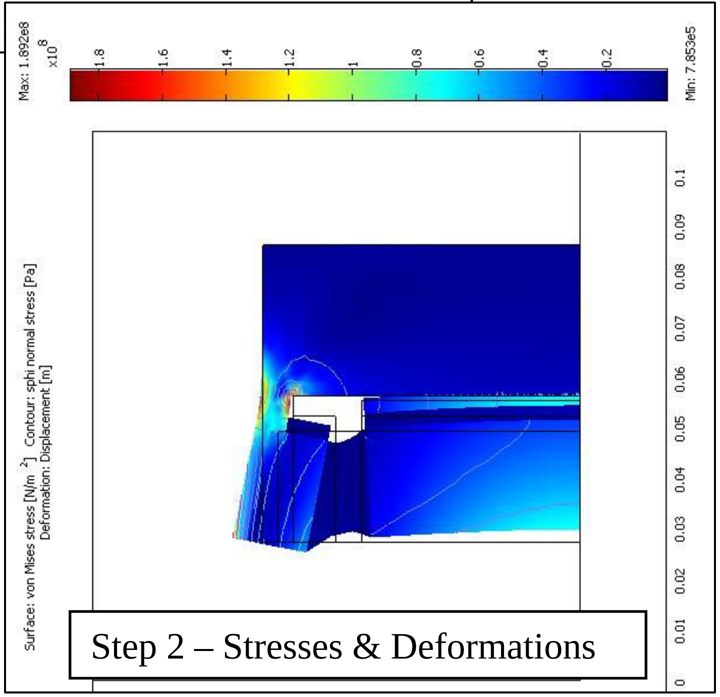
# RT section Solenoid R&D (1)

- **Focusing solenoids will provide axisymmetric beam**
  - Reduce beam halo formation
  - Integral field spec requires SC magnet

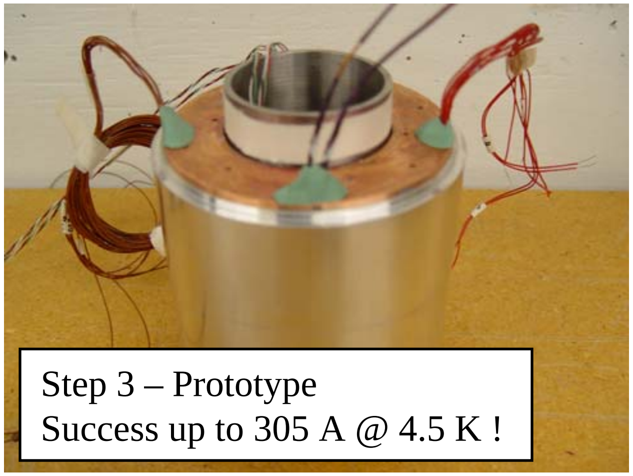
| | DTL | SSR | DSR |
|---|---|---|---|
| Number of solenoids in the section | 4(MEBT) + 19 | 18 (9 x 2) | **18 ?** |
| Parameter | | | |
| Bore diameter | 20 mm | 30 mm | 30 mm |
| Bore type | warm | cold | cold |
| Field Integral FI = $\int B^2 dl$ ($T^2 \cdot cm$) | **180 - 200** | 300 | **580** |
| Margin | **20 – 30%** | | |
| Recommended Bm (T) | | | < 6 |
| Leff (cm) @ Bm | < 10 cm | <10 cm | |
| Field extension | < 2*Leff | Sharp edges | Sharp edges |
| Available insertion gap (mm) | **235** | 315 | 320 |

Step 1 – Magnetic Modeling





Step 2 – Stresses & Deformations

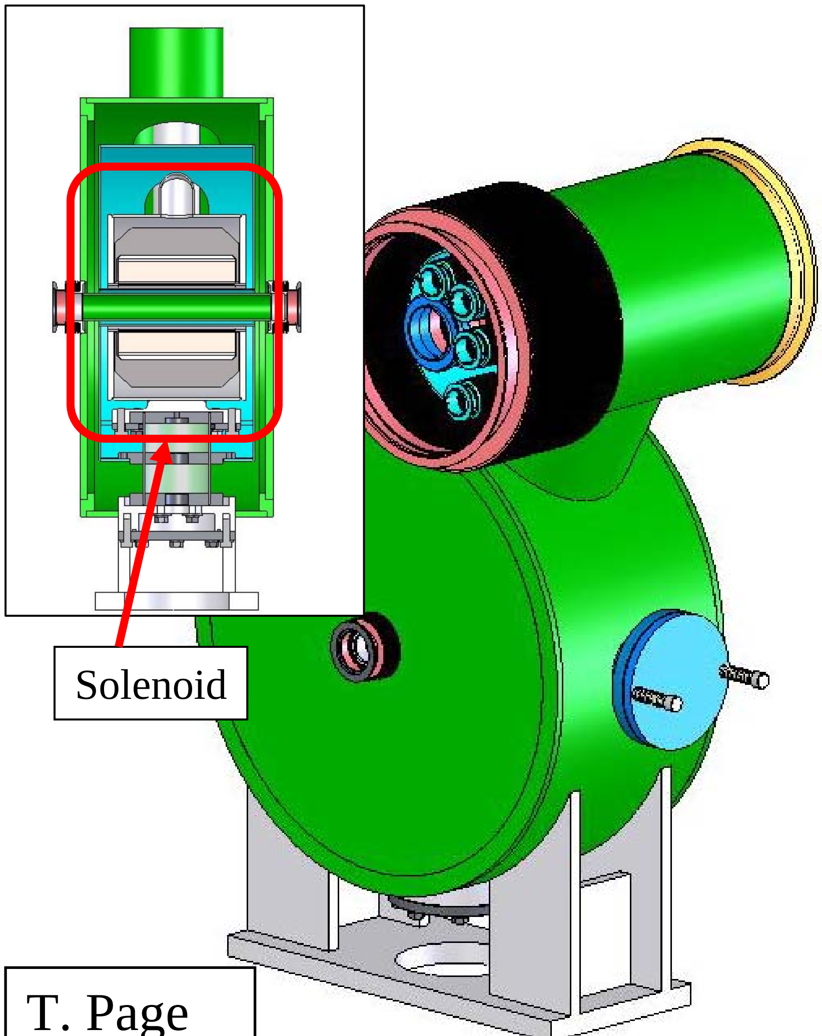


Step 3 – Prototype
Success up to 305 A @ 4.5 K !

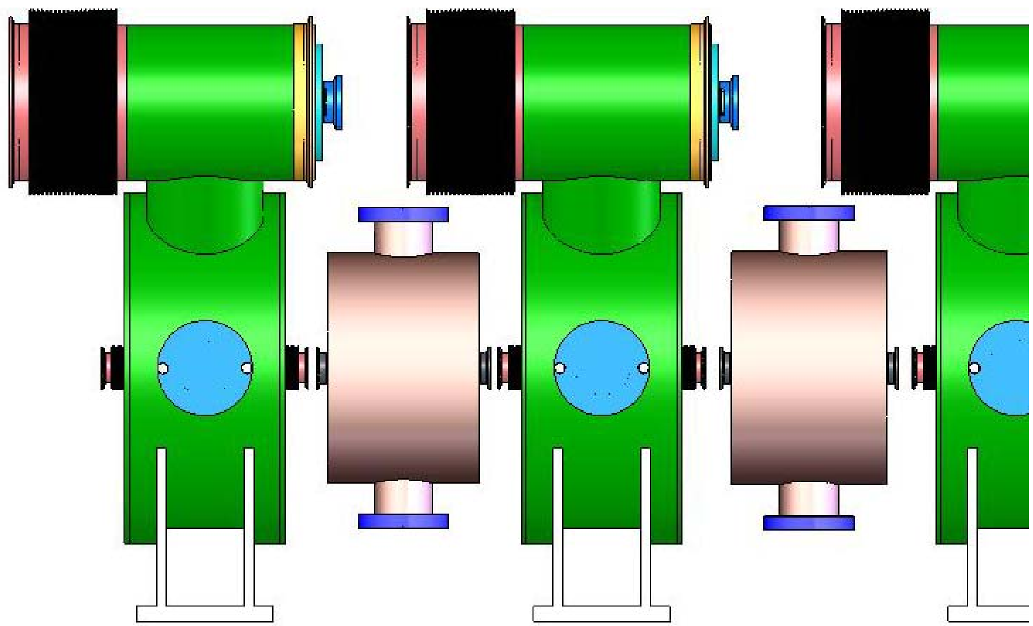
J. Tompkins
Y. Terechkine
(leaders)

# RT section Integration R&D

- **Solenoid Cryostat**




- **RT Solenoids/Cavities String**



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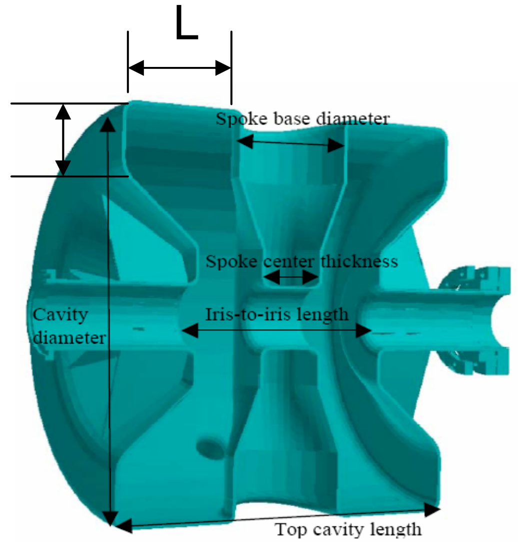
# SC Spoke Resonator R&D

- **Spoke Cavities and CryoModules**
  - Why Spokes
    - Fewer types & higher operating T (4 K)
    - Simulation shows good beam quality (increased longitudinal acceptance)
    - Superior mechanical stability for β<0.6
  - Decade-old technology (Delayen et al., LINAC 92)
  - Open to Elliptical cavities processing conditions
    - HPR
    - Clean Assembly
  - ANL $E_{acc}$ OK !

L. Giobatta
I. Gonin
T. Khabibouline
K. Shepard (ANL)




**R/Q**

| V \ L | 50 | 60 | 70 | 80 |
|---|---|---|---|---|
| 30 | 234.19 | 236.89 | 238.16 | 239.8 |
| 55 | 240.67 | 243.76 | 246.19 | 249.14 |
| 80 | 248.41 | 251.77 | 256.2 | 259.61 |
| 105 | 257.27 | 262.66 | 267.63 | 272.24 |

**Epeak/Eacc**

| | 50 | 60 | 70 | 80 |
|---|---|---|---|---|
| 30 | 2.86 | 2.83 | 2.73 | 2.69 |
| 55 | 2.83 | 2.74 | 2.72 | 2.66 |
| 80 | 2.84 | 2.69 | 2.64 | 2.62 |
| 105 | 2.69 | 2.64 | 2.61 | 2.55 |

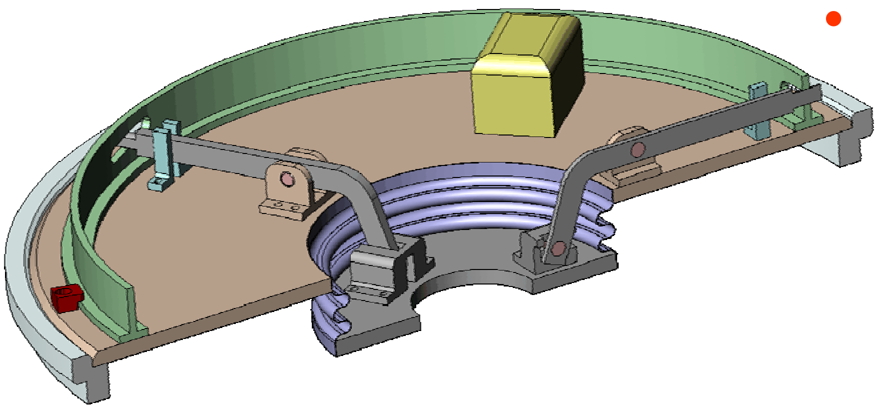
**Q**

| | 50 | 60 | 70 | 80 |
|---|---|---|---|---|
| 30 | 1.41E+09 | 1.44E+09 | 1.39E+09 | 1.45E+09 |
| 55 | 1.44E+09 | 1.50E+09 | 1.55E+09 | 1.51E+09 |
| 80 | 1.49E+09 | 1.53E+09 | 1.60E+09 | 1.65E+09 |
| 105 | 1.52E+09 | 1.58E+09 | 1.65E+09 | 1.71E+09 |

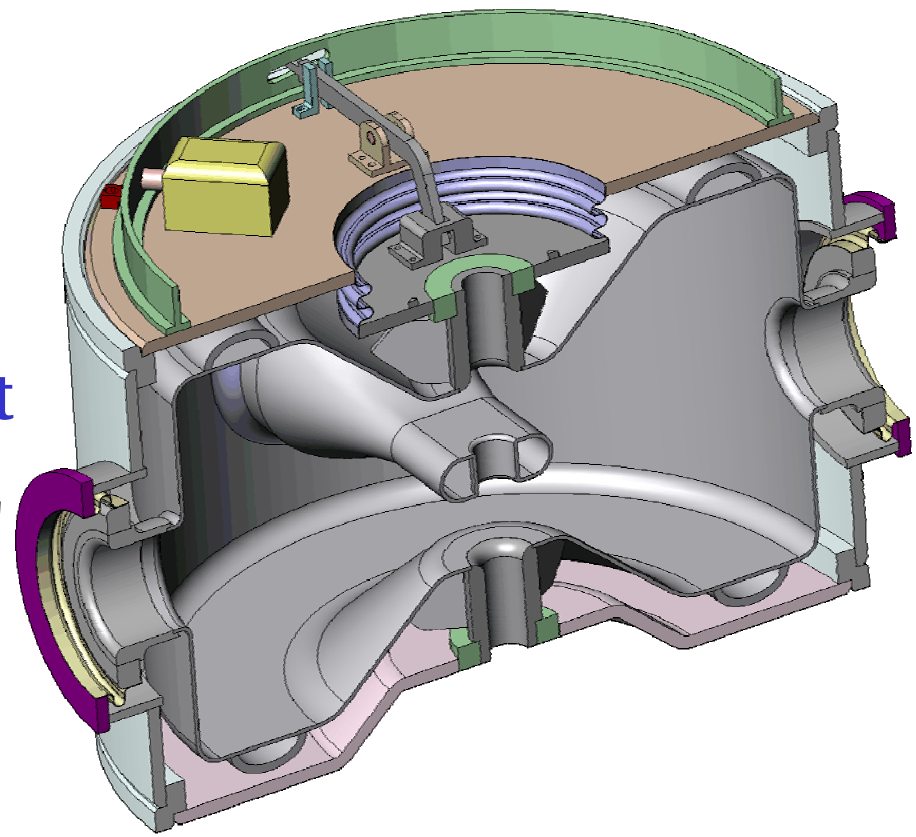
**Bpeak/Eacc**

| | 50 | 60 | 70 | 80 |
|---|---|---|---|---|
| 30 | 7.06 | 6.30 | 5.83 | 5.35 |
| 55 | 6.86 | 6.22 | 5.71 | 5.23 |
| 80 | 6.65 | 6.02 | 5.52 | 5.08 |
| 105 | 6.50 | 5.88 | 5.36 | 4.87 |

# SC Spoke Resonator R&D - β=0.22



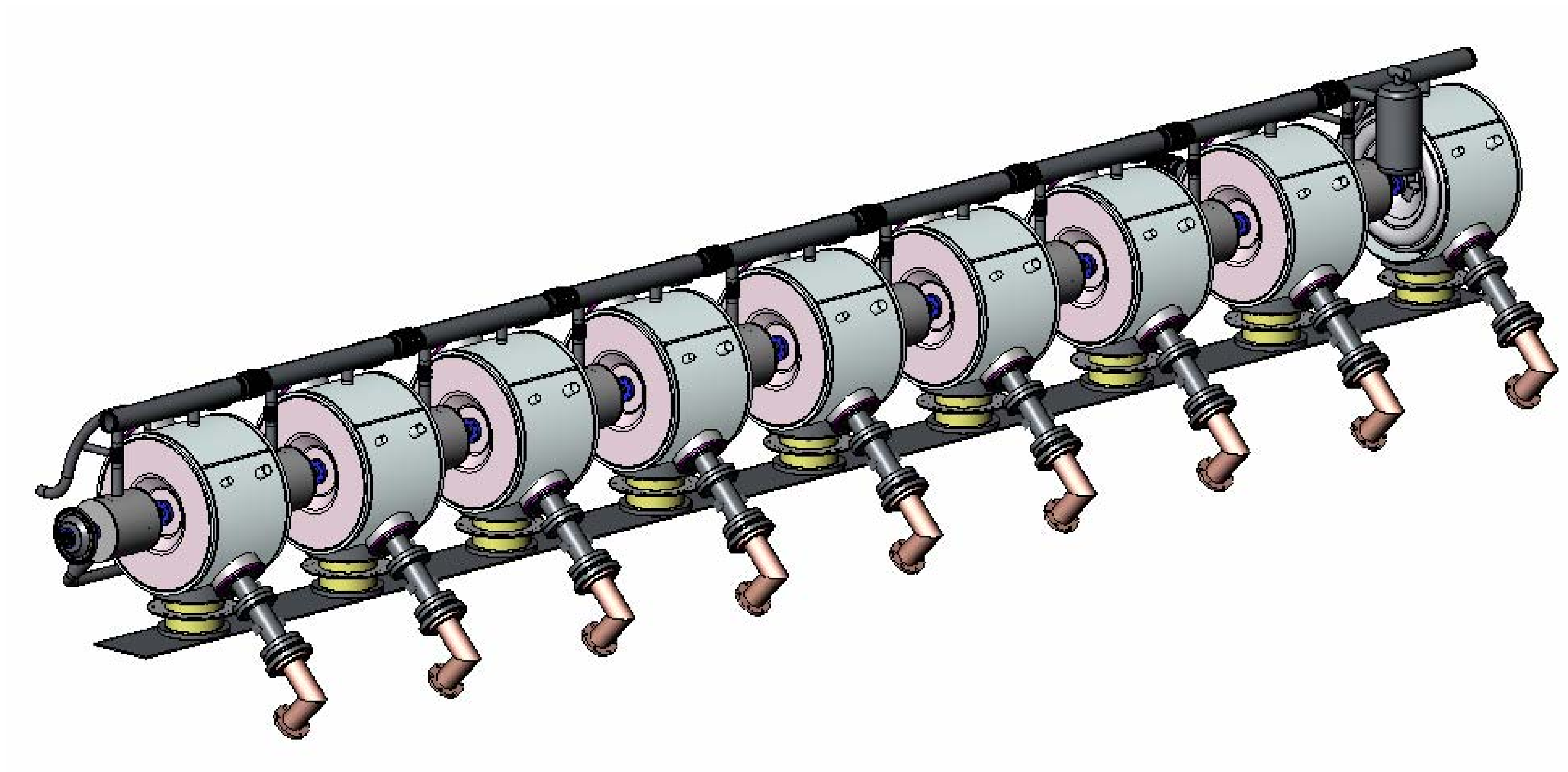
- **Slow Tuning Mechanism**
  - To be prototyped on Al Cavity
  - Tuning Range: ± 500 kHz



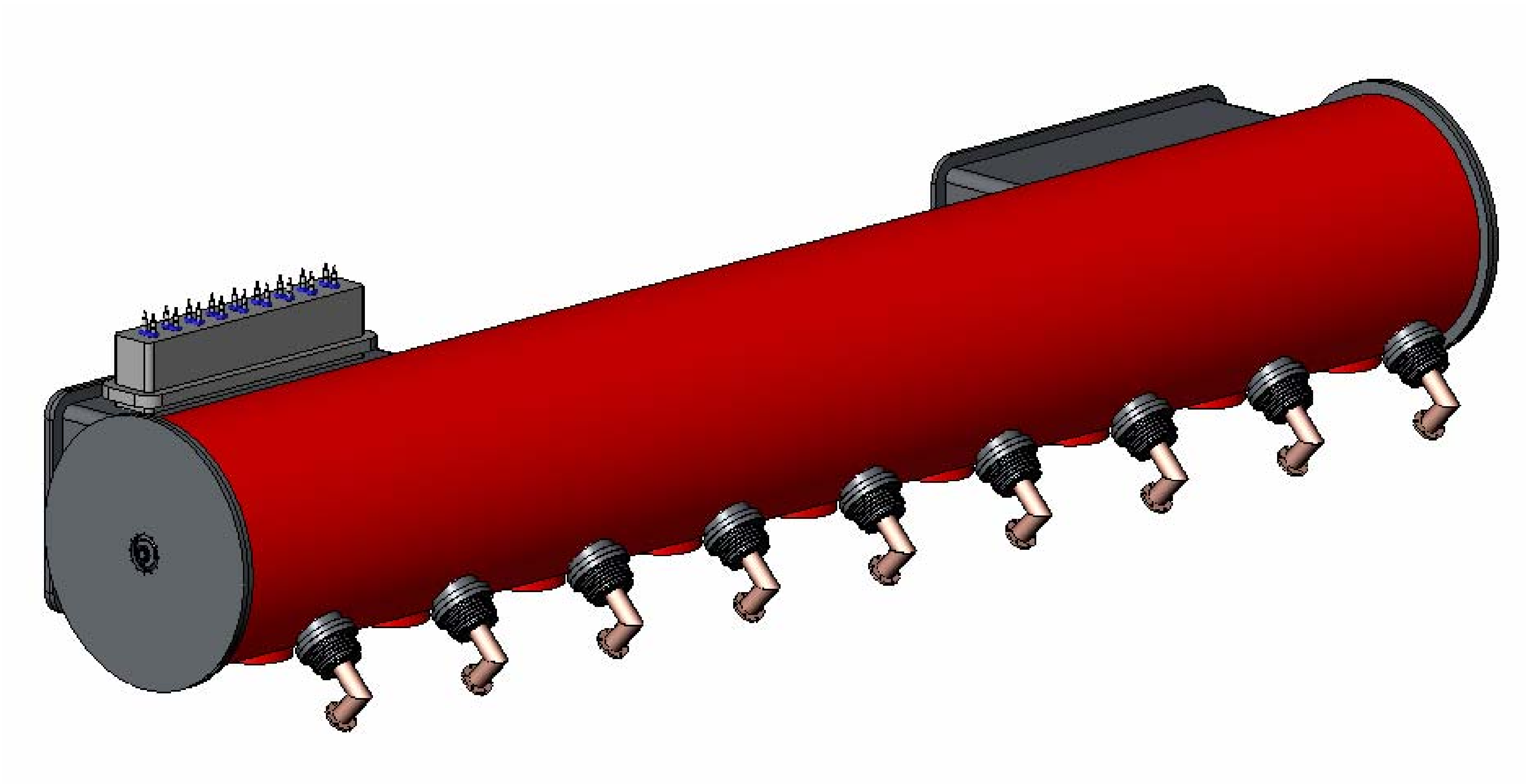
- **2 Prototype SC SSR Cavities under Procurement**
  - 1 "Sole Sourced" to AES. ANL Collaboration
  - 1 Open bid.

L. Giobatta

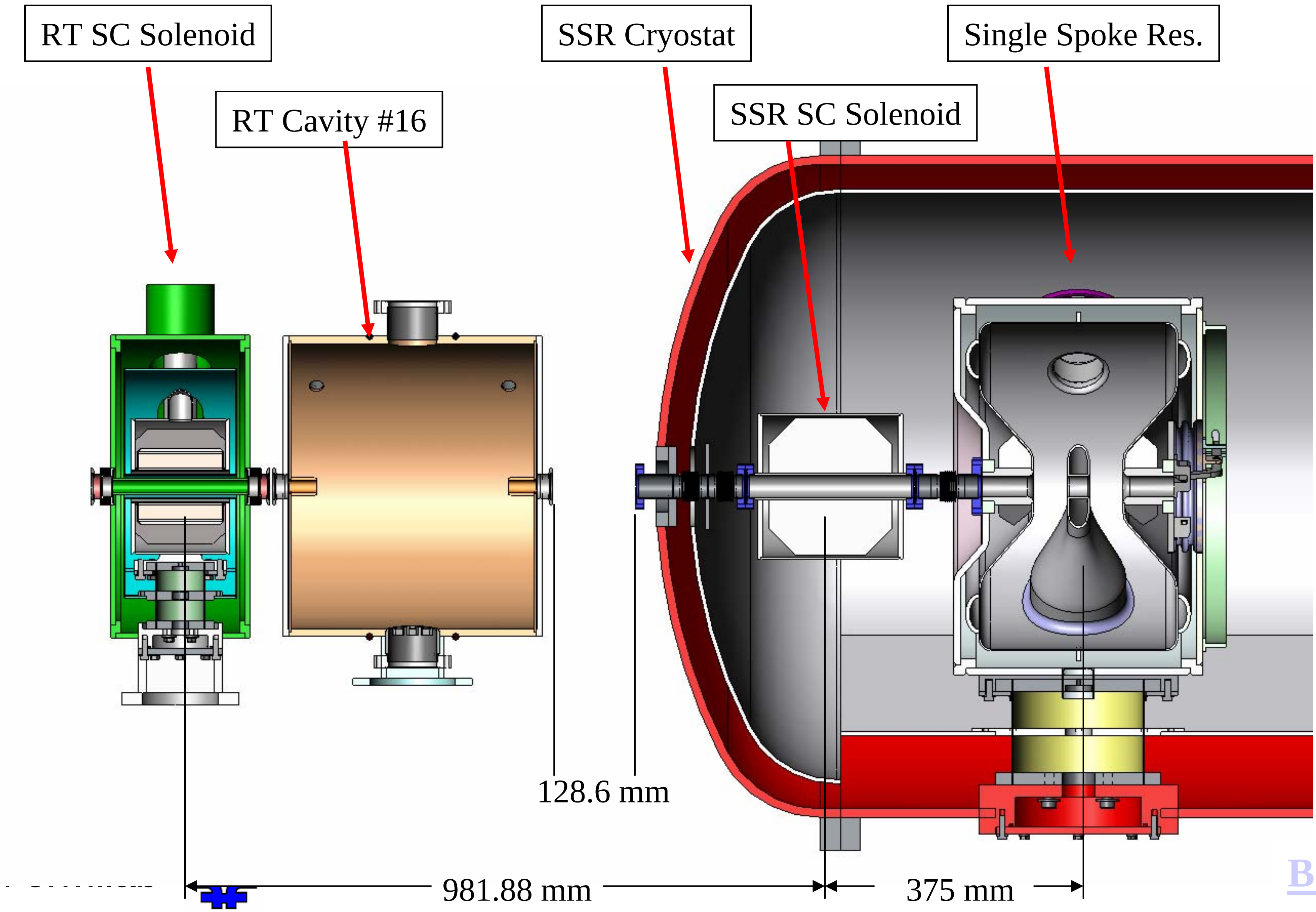
# β=0.22 Cold Mass Assembly



# β=0.22 Cryomodule Assembly

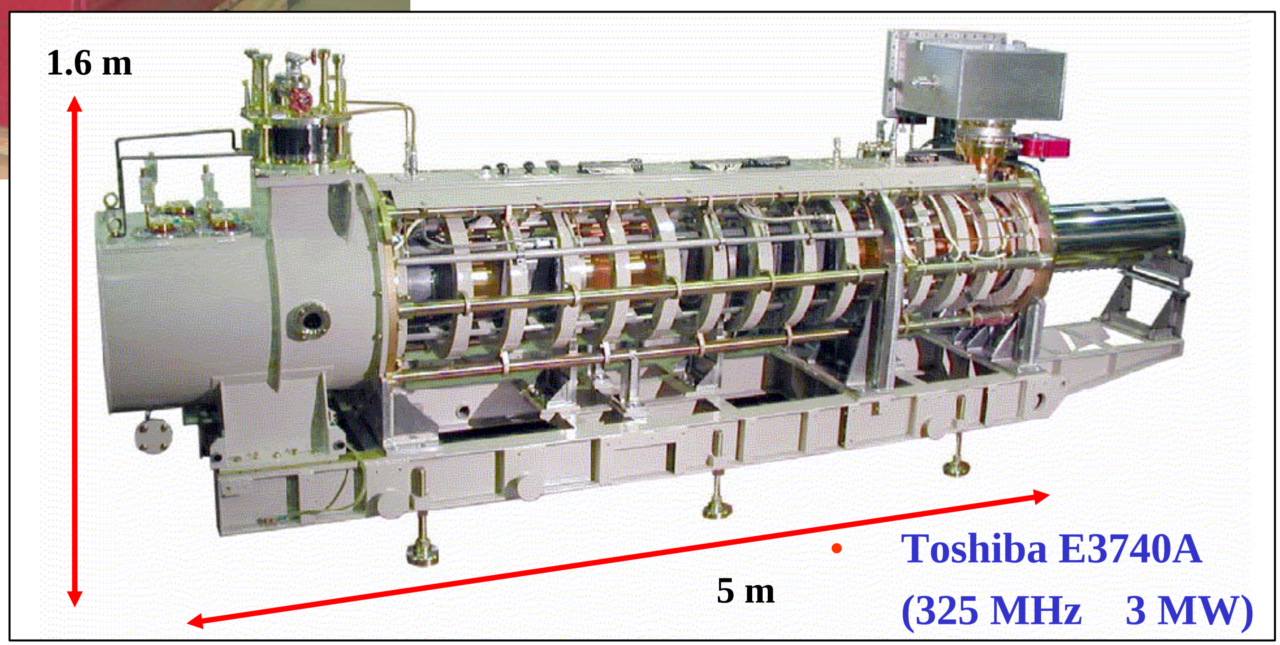


# Warm-Cold Integration




Back

# Modulator & Klystron in Meson




A. Moretti
B. Webber
B. Chase
J. Steimel

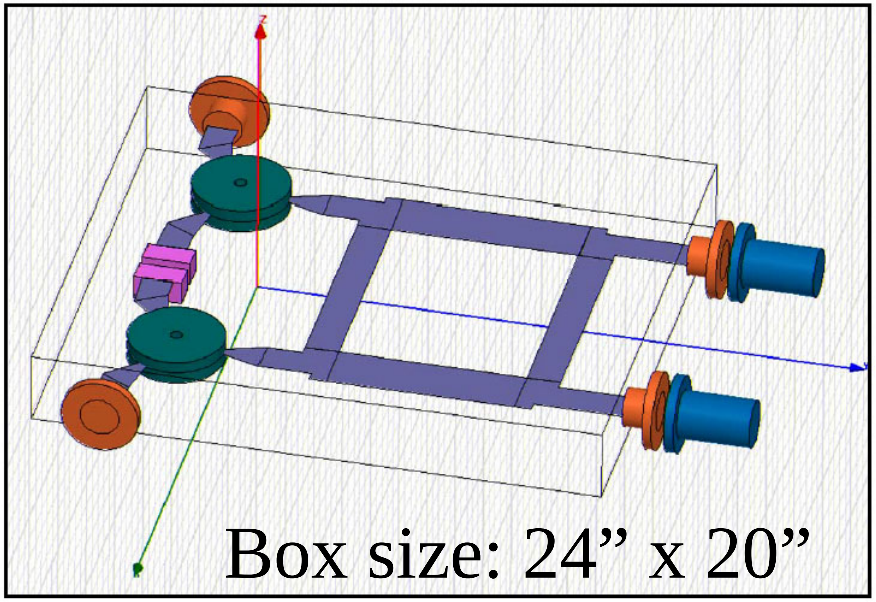
# IQ Modulator Function

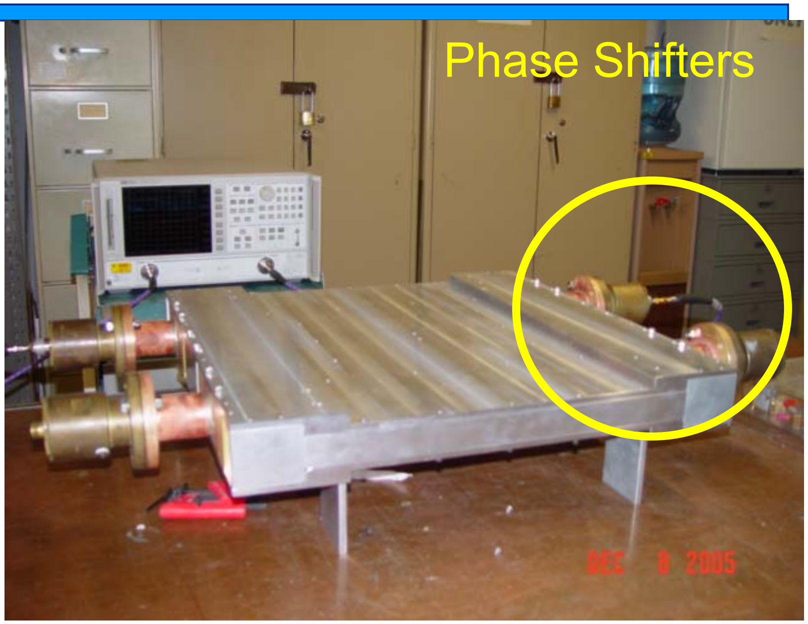
- **The entire front-end linac up to 90 MeV is powered by a single 2.5 MW klystron. RF power is carried by a single WR 2300 waveguide alongside the beam line and partially extracted by a coupler at the location of each RF structure.**
- **IQ modulators are used to control phase and amplitude of the input power for each RF structure.**
- **Crucial for financial feasibility of 8 GeV Linac (see SNS)**
- **Specs:**
  - Power
    - 40-120 kW (Cavities)
    - ~300 kW (RFQ)
  - Tuning Range & Slew Rate
    - +/- 45 degrees (phase), +/- 1.5 db
    - 1 degree/1 μsec

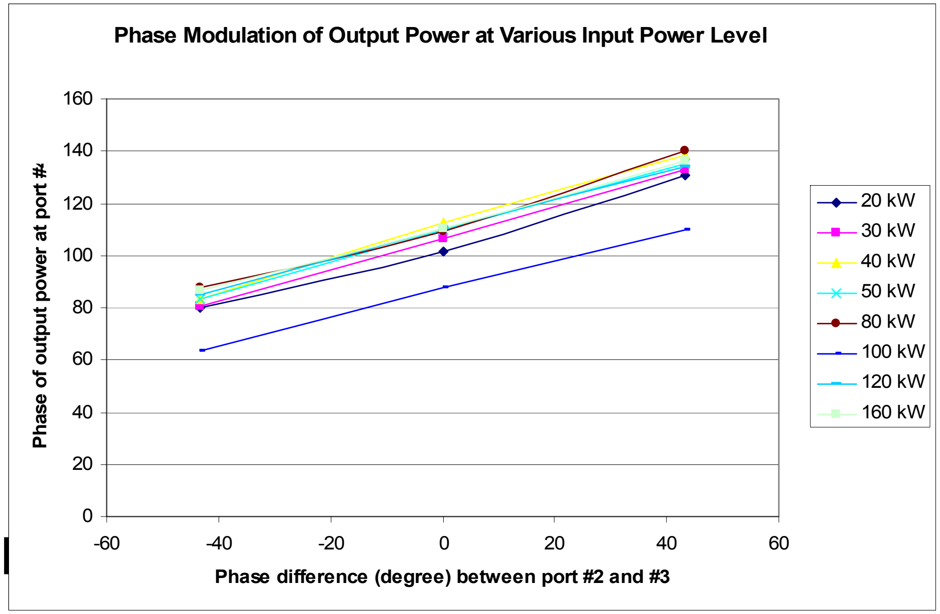


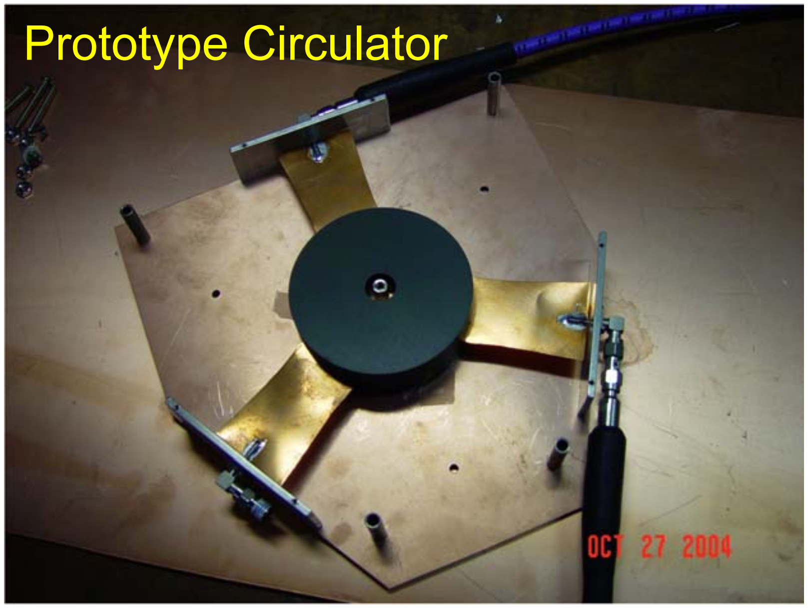
D. Wildman
D. Sun

# IQ Modulator & Coaxial Phase Shifters

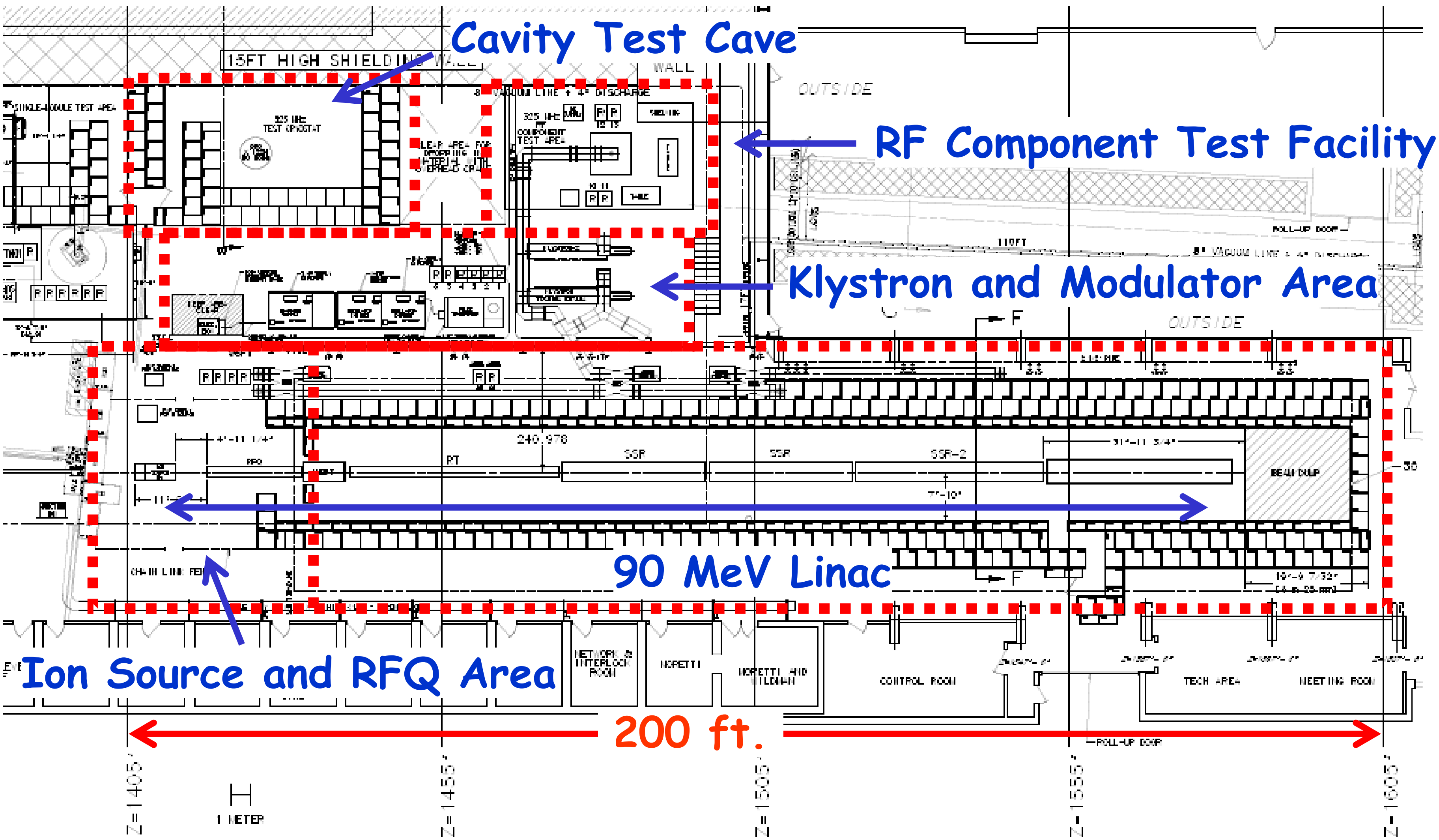


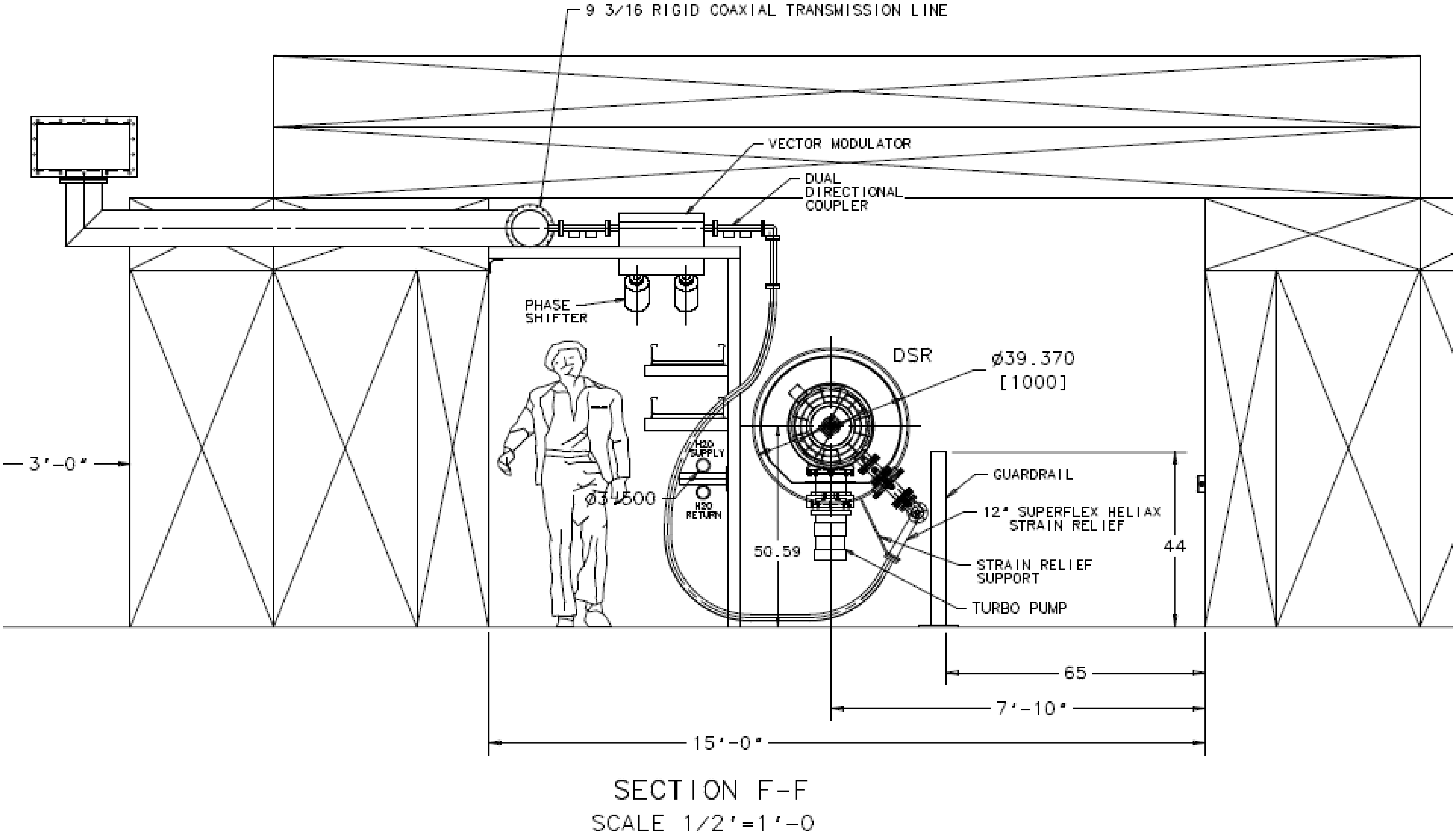



# Meson Building Floor Plan



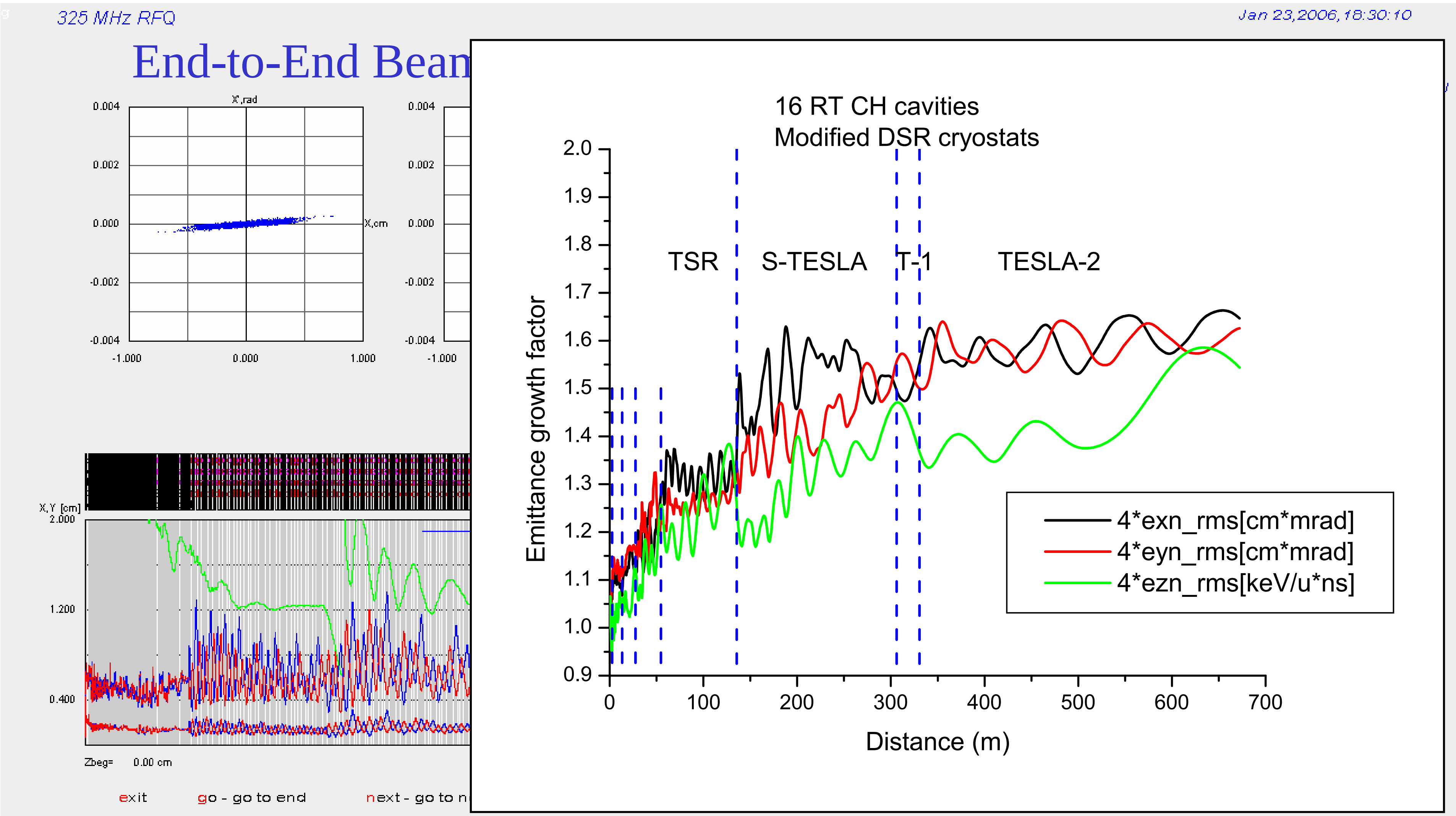
# View Down (Future) Linac Beam Line

# Meson Linac Cave Cross-section



# Full Linac Beam Design

- **Effort spearheaded by P.Ostroumov (ANL) & J.P. Carneiro(AD)**



- ✓ **Introduction**
- ✓ **HINS Plans (2006-2010)**
- ✓ **Ongoing R&D Activities**
- ❖ **Resources: *Collaborations*, Funding & Manpower**
- ❖ **Synergies and Comparisons**

# Critical Collaborations in Place

- **ANL –** *Strongly ongoing*
  - Beam Dynamics
  - Spoke Cavities Processing
- **MSU –** *Strongly ongoing*
  - $\beta$=0.81 Elliptical Cavities development
- **LBL -** *Starting*
  - Electron Cloud Effects in MI
  - Buncher Cavities
- **BNL –** *Still under negotiation*
  - Injection Studies
  - Stripping Foil Simulation & Engineering
  - Laser Beam Profiler
- **FY06 SOW: ~2.2 M$**

# HINS R&D Manpower Resources

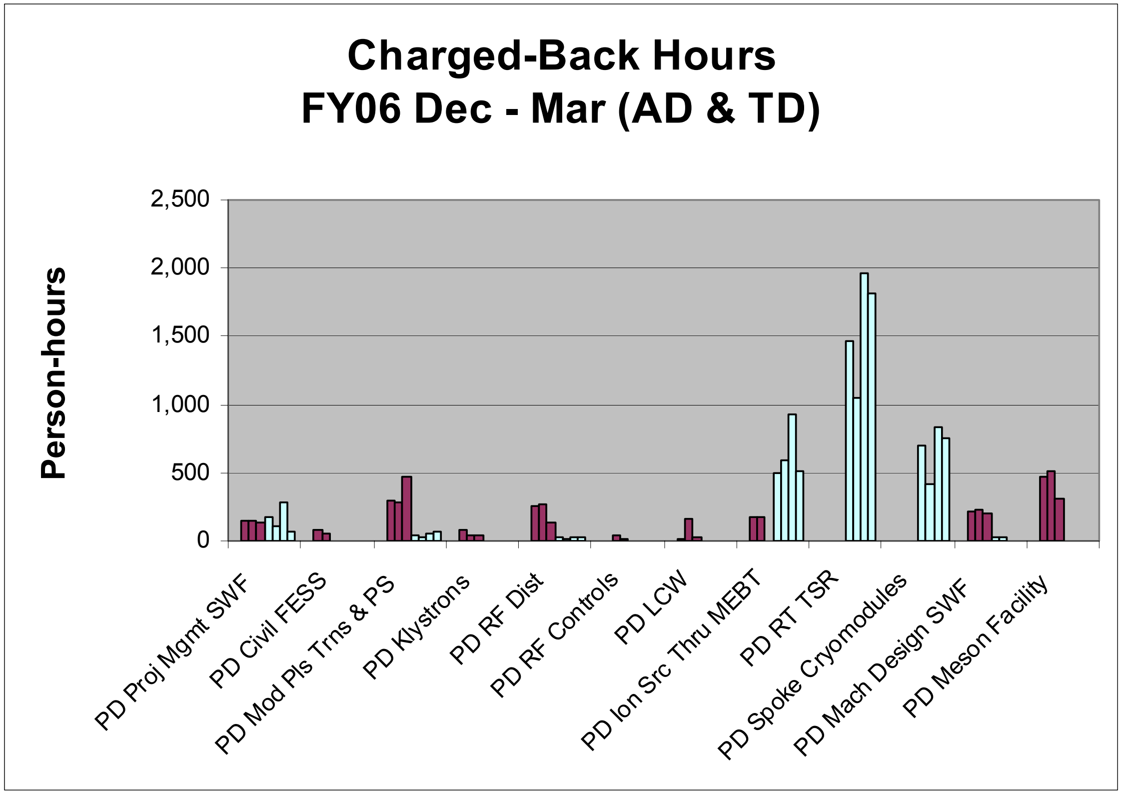
| (All) | FY05 | FY06 | FY07 | FY08 | FY09 | FY10 |
|---|---|---|---|---|---|---|
| LABOR | | | | | | |
| CDF PROGRAM | 2,442.6 | 2,965.1 | 3,098.4 | 3,079.1 | 3,202.3 | 3,330.4 |
| D-ZERO PROGRAM | 2,502.0 | 2,773.3 | 2,898.0 | 2,897.2 | 3,013.1 | 3,133.6 |
| MINIBOONE, FT EXPS & EXT BEAMS | 1,392.7 | 1,286.2 | 1,272.5 | 879.9 | 915.1 | 951.7 |
| NOvA | 835.7 | 2,031.7 | 4,017.5 | 4,910.1 | 5,106.5 | 5,310.8 |
| MINERvA | 324.0 | 1,094.2 | 2,732.0 | 2,413.9 | 1,350.0 | 1,404.0 |
| OTHER EXPERIMENTAL INITIATIVES | 1,089.3 | 1,993.6 | 2,123.3 | 2,124.3 | 2,209.3 | 2,297.6 |
| NuMI / MINOS | 1,281.8 | 690.1 | 721.2 | 755.8 | 786.0 | 817.5 |
| LINEAR COLLIDER - GDE | 18.2 | 3,927.2 | 7,542.3 | 8,475.7 | 8,814.7 | 9,167.3 |
| LINEAR COLLIDER - FNAL | 1,925.9 | 2,760.0 | 7,000.0 | 7,825.0 | 8,138.0 | 8,463.5 |
| LINEAR COLLIDER - DETECTOR | 1,100.8 | 1,459.5 | 2,088.6 | 2,168.4 | 2,255.1 | 2,345.3 |
| RF INFRASTRUCTURE | 4,297.4 | 5,097.0 | 3,402.7 | 6,653.2 | 6,919.3 | 7,196.1 |
| HIGH INTENSITY NEUTRINO SOURCE | 2,238.1 | 3,859.1 | 4,087.0 | 4,226.0 | 4,395.0 | 4,570.8 |
| SC MAGNETS & OTHER FUTURE ACCEL | 3,082.7 | 3,174.6 | 3,300.5 | 3,451.2 | 3,589.2 | 3,732.8 |
| THEORY | 3,361.2 | 3,103.0 | 3,242.7 | 3,398.3 | 3,534.2 | 3,675.6 |
| ASTRO THEORY | 938.8 | 1,085.2 | 1,145.0 | 1,211.7 | 1,260.2 | 1,310.6 |
| LATTICE GAUGE | 529.5 | 1,117.9 | 1,227.5 | 1,286.4 | 1,337.8 | 1,391.3 |
| SDSS | 1,950.1 | 1,461.6 | 1,539.3 | 1,625.7 | 1,690.8 | 1,758.4 |
| CDMS | 848.3 | 1,283.1 | 1,340.9 | 1,405.3 | 1,461.5 | 1,519.9 |
| PIERRE AUGER | 1,069.6 | 1,380.7 | 1,443.0 | 1,512.4 | 1,572.9 | 1,635.8 |
| JDEM | 573.2 | 939.0 | 964.5 | 1,010.8 | 1,051.2 | 1,093.3 |
| DARK ENERGY SURVEY | 1,453.9 | 2,128.4 | 2,465.2 | 2,583.5 | | |
| LHC BASE SUPPORT | 3,608.9 | 4,319.1 | 4,759.2 | 4,986.9 | | |
| LHC PROGRAM | 7,299.2 | 9,020.4 | 8,187.1 | 8,551.6 | | |

ESTIMATED FY06 FTE AS OF 10-31-05

| | |
|---|---|
| CDF PROGRAM | 23.2 |
| D-ZERO PROGRAM | 21.7 |
| MINIBOONE, FT EXPS & EXT BEAMS | 11.4 |
| NOvA | 19.7 |
| MINERvA | 10.1 |
| OTHER EXPERIMENTAL INITIATIVES | 24.1 |
| NuMI / MINOS | 7.4 |
| LINEAR COLLIDER - GDE | 42.9 |
| LINEAR COLLIDER - FNAL | 30.2 |
| LINEAR COLLIDER - DETECTOR | 17.6 |
| RF INFRASTRUCTURE | 31.8 |
| HIGH INTENSITY NEUTRINO SOURCE | 33.6 |
| SC MAGNETS & OTHER FUTURE ACCEL | 38.2 |

Fermilab

# HINS R&D Manpower: FY06 Experience




- **Average ~4,800 h/month (AD+TD)**
- **~28 charged-FTE or ~33 warm-bodied-FTE (85% ε)**
  - On low end of FY06 plans (22 FTEs in TD + 10-15 FTEs in AD)

# HINS R&D Human Resources

| *AD* | '06 | '07 | '08 |
|---|---|---|---|
| Beam Physics Design | 2 | 2 FTE | 2 FTE |
| Ion Source | [illegible] | 1.5 FTE | .2 |
| Klystron & Modulator | [illegible] | 0.5 FT | ----- |
| RF Power Distrib. | [illegible] | 1.5 | 0.5 FTE |
| IQ Modulators | [illegible] | [illegible] | 1 FTE |
| Low Level RF | [illegible] | [illegible] | 3 TE |
| Beam Instrumen | [illegible] | [illegible] | E |
| Cryogenics | [illegible] | [illegible] | [illegible] |
| Stands & Alignment | E | [illegible] | [illegible] |
| Magnet Power | FTE | [illegible] | [illegible] |
| Vacuum Systems | 0.2 FTE | TE | [illegible] |
| Controls & Software | 1 FTE | FTE | [illegible] |
| Safety Systems | 0.5 FTE | 1 FTE | TE |
| Installation | 1 FTE (0.5 FTE) | 2 FTE | FTE |
| Integration/Ops. | 0.5 FTE | 1.5 FTE | 2 FTE |

**FY06 Needs**
5 Scientists
12.5 Eng (2 Guests)
8 Drafters
~14 Techs & Support
6 Un-identified (20%)

**FY07 Needs**
6 Scientists
14 Eng (1 Guest)
8 Drafters
~21 Techs & Support

**FY08 Needs**
6 Scientists
11.5 Eng
14 Drafters
7+ Techs

**Continued technical support is absolutely necessary. Loss of technical support for any of the R&D aspects will prevent the achievement of one or more of the 5 goals in the "0 to 90 MeV Front End" HINS Program**

# HINS R&D M&S Resources

| | | | | | | |
|---|---|---|---|---|---|---|
| M&S | | | | | | |
| CDF PROGRAM | 155.1 | 251.0 | 257.0 | 263.0 | 269.6 | 236.4 |
| D-ZERO PROGRAM | 285.4 | 225.0 | 230.0 | 236.0 | 241.9 | 247.9 |
| MINIBOONE, FT EXPS & EXT BEAMS | 188.0 | 142.4 | 124.6 | 122.6 | 125.7 | 128.8 |
| NOvA | 635.1 | 3,110.0 | 7,959.0 | 37,971.7 | 58,104.8 | 42,088.7 |
| MINERvA | 632.6 | 16.0 | 2,000.0 | 3,400.0 | 2,750.0 | 100.0 |
| OTHER EXPERIMENTAL INITIATIVES | 403.5 | 491.9 | 1,016.0 | 526.3 | 539.5 | 552.9 |
| NuMI / MINOS | 710.3 | 217.3 | 222.8 | 228.3 | 234.0 | 239.8 |
| LINEAR COLLIDER - GDE | 316.9 | 5,766.0 | 14,371.0 | 30,327.0 | 31,085.2 | 31,862.3 |
| LINEAR COLLIDER - FNAL | 2,827.1 | 1,657.0 | 6,000.0 | 6,000.0 | 6,150.0 | 6,303.8 |
| LINEAR COLLIDER - DETECTOR | 273.9 | 414.7 | 1,050.0 | 2,100.0 | 2,152.5 | 2,206.3 |
| RF INFRASTRUCTURE | 3,211.9 | 3,560.0 | 4,900.0 | 5,900.0 | 6,047.5 | 6,198.7 |
| HIGH INTENSITY NEUTRINO SOURCE | 2,147.1 | 6,446.0 | 5,735.3 | 5,879.5 | 6,026.5 | 6,177.1 |
| SC MAGNETS & OTHER FUTURE ACCEL | 1,831.9 | 1,381.2 | 1,647.6 | 1,670.6 | 1,712.3 | 1,755.1 |
| THEORY | 237.3 | 428.5 | 489.2 | 501.4 | 513.9 | 526.8 |
| ASTRO THEORY | 192.2 | 180.0 | 209.5 | 214.7 | 220.1 | 225.6 |
| LATTICE GAUGE | 922.4 | 1,664.4 | 1,506.0 | 1,748.6 | 1,792.4 | 1,837.2 |
| SDSS | 280.7 | 277.9 | 284.9 | 292.0 | 299.3 | 306.7 |
| CDMS | 721.3 | 459.5 | 471.0 | 482.7 | 494.8 | 507.2 |
| PIERRE AUGER | 584.3 | 250.0 | 256.4 | 261.0 | 267.5 | 274.2 |
| JDEM | 67.4 | 67.7 | 69.4 | 71.1 | 72.9 | 74.7 |
| DARK ENERGY SURVEY | 956.2 | 1,489.2 | 2,091.4 | 3,416.5 | 2,598.1 | 860.0 |
| LHC BASE SUPPORT | 494.3 | 517.4 | 893.5 | 915.8 | 938.7 | 962.1 |
| LHC PROGRAM | 13,732.6 | 14,128.4 | 15,386.9 | 14,416.1 | 14,768.1 | 15,128.7 |

~23 M$ in FY07-FY10

# HINS M&S Procurement Plans in FY07-FY10

| *Cost* | *FY05 Estimate* | *FY07-FY10* |
|---|---|---|
| • Ion Source-LEBT | 350 k$ | 100 k$ |
| • RFQ | 1200 k$ | ~ done |
| • MEBT | 220 k$ | *~ 400 k$* |
| • RT | 1130 k$ | 1130 k$ |
| • SSR1 Cryo 1-2 | 3365 k$ | *~ 4228 k$* |
| • SSR2 Cryo 3-4 | 6468 k$ | *~ 5260 k$* |
| • IQM | 3586 k$ | *~ 2000 k$* |
| • Klystron | 600 k$ | ~done |
| • Modulator | 783 k$ | ~done |
| • (beam diag., LLRF..) | 1430 k$ | 1430 k$ |
| • Civil | - | 300 k$ |
| • Collaborations (?) | - | ~ 5000 - 8000 k$ |
| • Operations | - | ~ 2000 k$ |
| • Total | 19,132 k$ | ~22 – 25 M$ |

- Hard to keep FY06 level of HINS Collaboration in out years
- Descoping venue: eliminate Cryo #4

# Synergies and Comparisons

- **Addressed by AAC Review on May 8-10th**
- **Several MOU-driven Collaborations in place for work on HINS. Avoid "duplication" of work.**
- **R&D Technical Synergies (with ILC)**
  - Long Pulse Modulators
  - Ferrite Vector Modulators
  - Superconducting Tuners
  - $\beta$=0.81 Elliptical Cavity Development
- **Comparison with other Accelerator R&D**
  - RIA (Spoke Cavities Development)
  - $\mu$ production/acceleration ( $\nu$ Factory & $\mu$ Collider R&D)

# Conclusion

- **Feasible R&D Plan in place**
- **Activities gearing up for success**
- **Manpower and M&S resources**
  - Available
  - Possible concerns on
    - Technical & Scientific Manpower resources
    - Funding in out-years