

RF Support for Test Facilities

Mark Champion

Fermilab Technical Division
SRF Development Dept.

The SCRF RF Group bridges Lab divisions



- RF expertise exists in multiple lab divisions
- Groups / Leads supporting SCRF include:
- Accelerator Division
 - High Level RF / John Reid
 - Low Level RF / Brian Chase
 - RF Dept / Ralph Pasquinelli
 - HINS 325 MHz RF / Al Moretti & Dave Wildman
 - High Voltage Modulators / Chris Jensen
- Technical Division
 - RF Structure design, modeling and measurements / Nikolay Solyak
 - Test and Instrumentation / Ruben Carcagno
- Computing Division
 - Electronic Systems Engineering / Gustavo Cancelo

SCRF Facilities Requiring RF Support



Facility	Location	Frequency	Power
Vertical Test Facility	IB1	1.3 GHz	500 W solid-state amplifier
Horizontal Test Facility	MDB	1.3 GHz 3.9 GHz	300 kW klystron 80 kW klystron (planned)
Capture Cavity II Test Facility	MDB	1.3 GHz	300 kW klystron
High Intensity Neutrino Source (HINS)	MDB	325 MHz	3 MW klystron
ILC Test Accelerator	NML	1.3 GHz 3.9 GHz	10 MW, 5 MW, 300 kW klystrons 80 kW klystron
A0 Photo Injector	A0	1.3 GHz	5 MW klystron (will move to NML) 300 kW klystron (will move to NML)
Single-Cell Vertical Test Facility (planned)	A0	1.3 GHz	500 W solid-state amplifier
Third-Harmonic Vertical Test Facility	A0	3.9 GHz	200 W TWT amplifier
Third-Harmonic RF Test Stand	A0	3.9 GHz	80 kW klystron (will move to Meson)

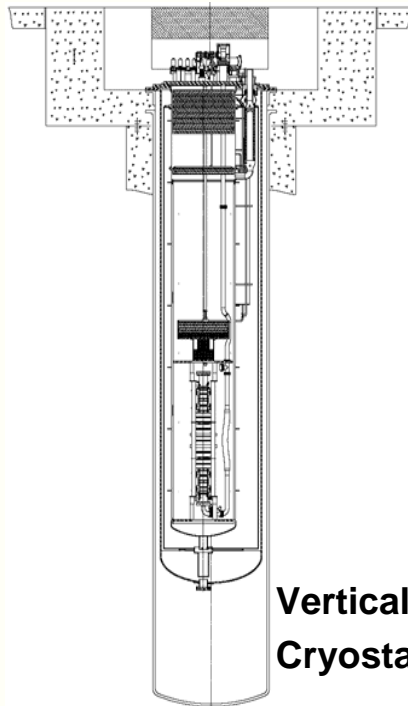
RF Amplifier Inventory and Plans



Klystron Amplifier	Application	Location	Present	Future
1.3 GHz, 10 MW Multi-Beam klystron	Cryomodules	NML	0	1
1.3 GHz, 5 MW klystron	RF Gun Cryomodule	A0, NML NML	2	3
1.3 GHz, 300 kW klystron	Capture Cavities Horizontal Test	A0, MDB, NML MDB	4	5
1.3 GHz, 500 kW klystron	Capture Cavity II	MDB	0	1
3.9 GHz, 80 kW klystron	Horizontal Test Coupler Test 3 rd Harmonic CM	MDB A0 → NML	1	2
325 MHz, 3 MW klystron	HINS	MDB	1	1
1.3 GHz, ~3 MW, TH-2095A, mod-anode klystron	Spare	Storage	5	5
3.9 GHz, 3 kW CW klystron	Spare	Storage	1	1

IB1 Vertical Test Facility – 1.3 GHz

- The IB1 Vertical Test Facility will support high-gradient, CW RF testing of 1.3 GHz cavities
- The 1.3 GHz 500 W solid-state amplifier and related RF chassis are installed and ready to support cavity testing in summer 2007
- This system has been designed in collaboration with JLab
- See Camille Ginsburg's talk for more details



Vertical Test
Cryostat Design

Vertical Test
Control Console



A0 Vertical Test Facility – 3.9 GHz

- The A0 Vertical Test Facility supports high-gradient CW RF testing of 3.9 GHz cavities
- It was established ~2000 to support development of a RF Separator
- SCRF RF personnel perform cavity tests in this facility



Cavity in preparation for testing



Vertical Test Console with dewar and test cave in background

Horizontal Test Facility at MDB

- The Horizontal Test Facility will support high-gradient, pulsed RF testing of “dressed” 1.3 and 3.9 GHz cavities
- The 1.3 GHz RF system is operational and ready to support horizontal tests (presently used for Capture Cavity II studies)
- The 3.9 GHz RF system – presently at A0 – will be installed in April
- See Andy Hocker’s talk for more details



1.3 GHz, 300 kW RF system



Horizontal Test Cryostat in preparation for 1st cooldown

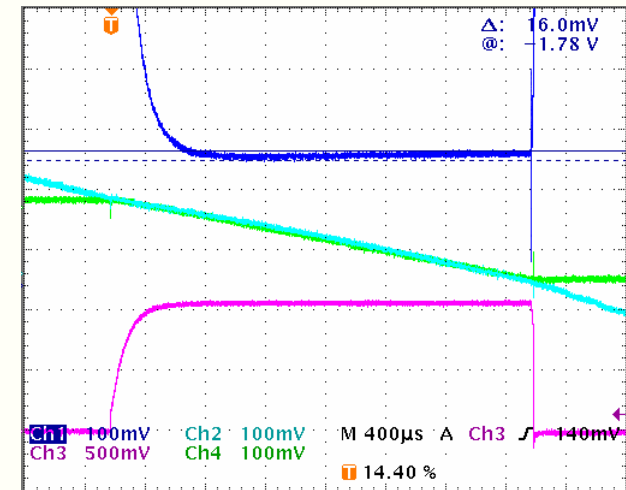


High-Voltage Modulators

- Modulators for the >1 MW klystrons are provided by the AD/EE Support group
- The “bouncer” configuration is a reliable design first deployed at DESY in mid 90’s
- Three in service at DESY; one in commissioning at MDB; one for future use at NML
- SLAC working on Marx Modulator for use with 10 MW multi-beam klystrons

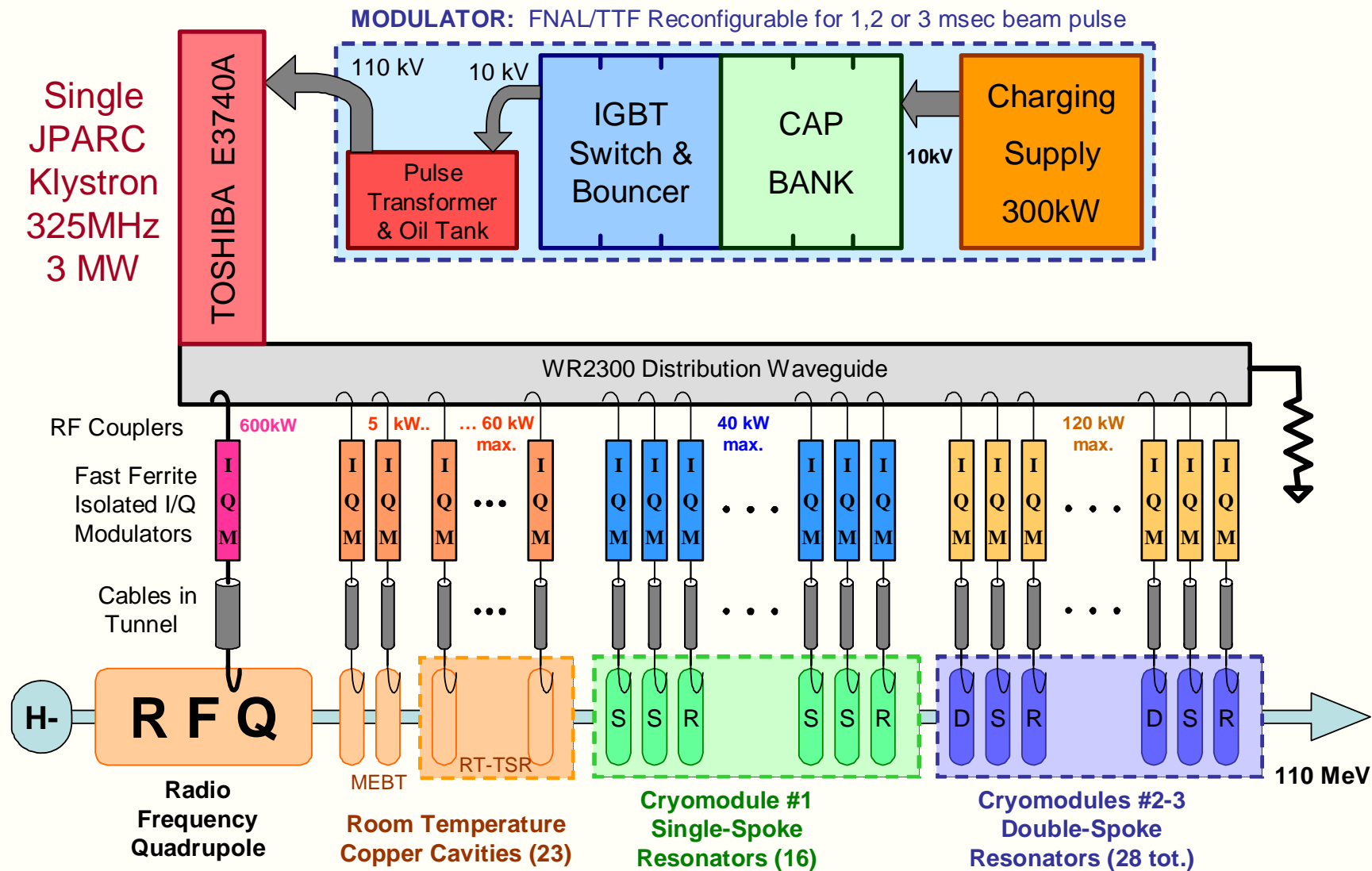


Views of crowbar switch, chokes, and capacitor bank.



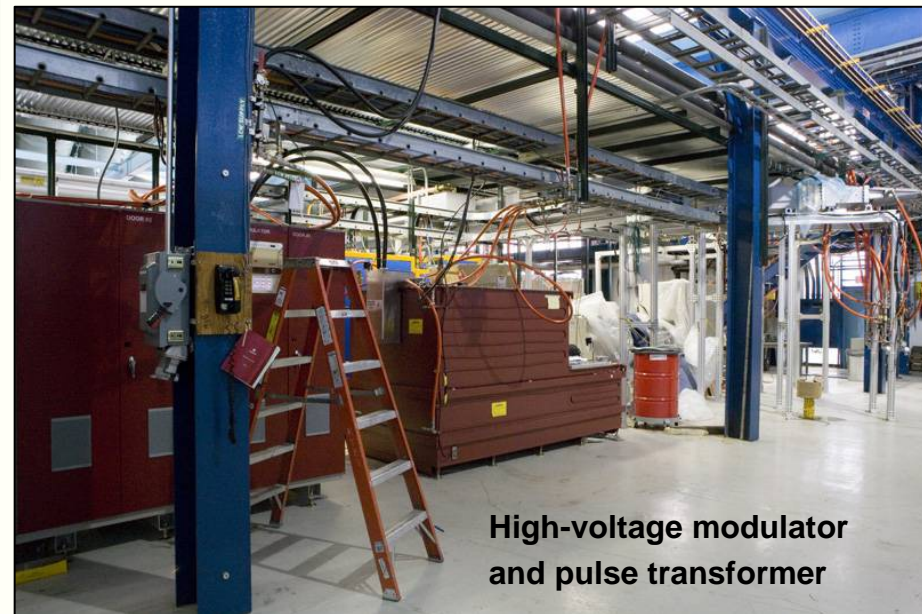
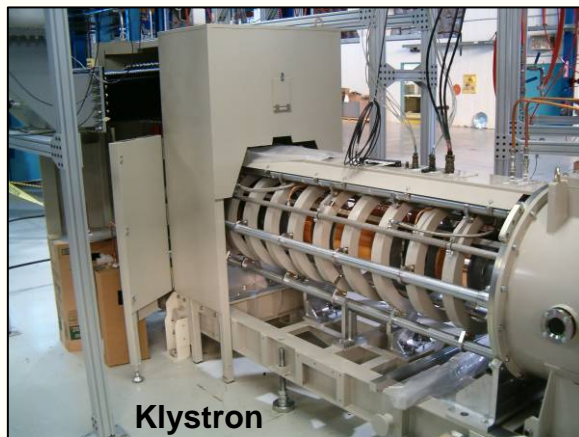
Demonstration of < 1% voltage regulation (blue trace)

HINS 325 MHz RF System

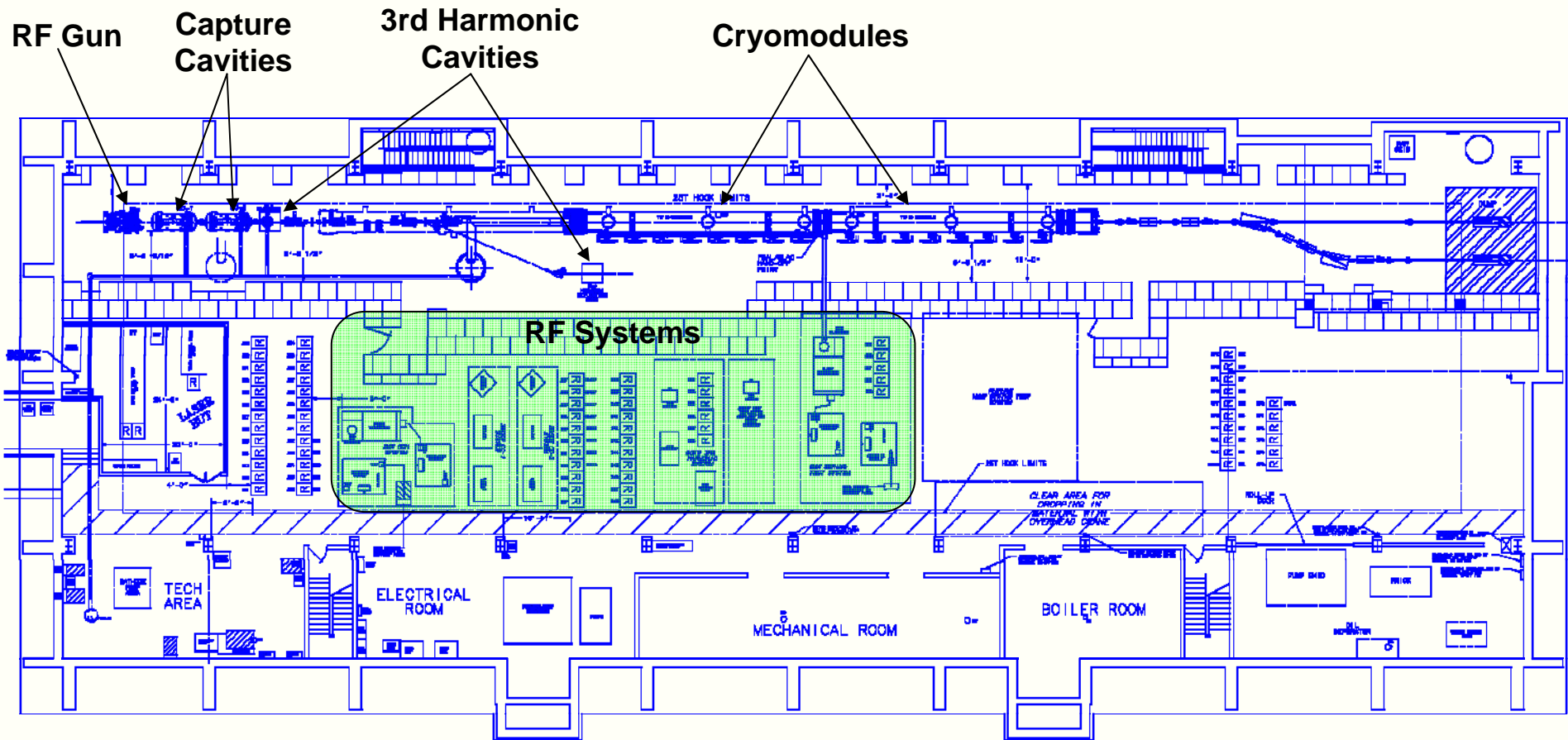


HINS 325 MHz RF System

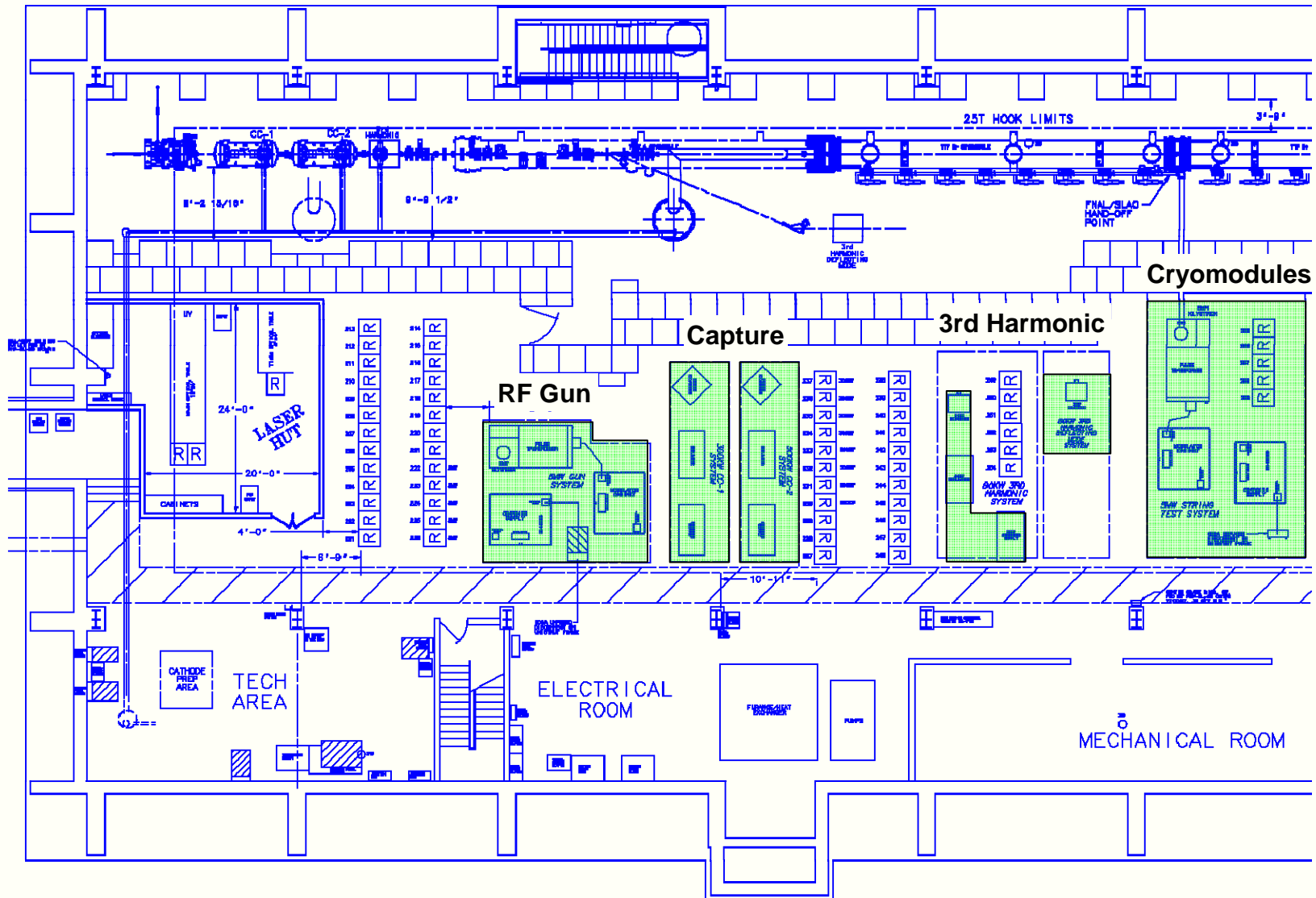
- The HINS RF system is installed at MDB
- Modulator testing in progress
- Brian Chase et al will provide LLRF control system
- ORNL will deliver modified SNS LLRF control system as well
- See Bob Webber's talk for more details



ILC Test Accelerator Layout at NML

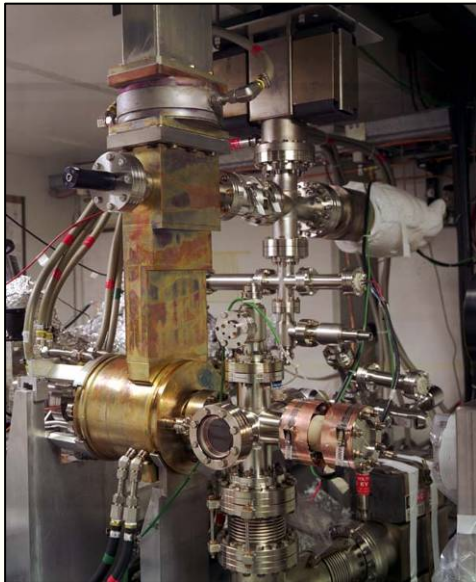


ILC Test Accelerator RF Systems

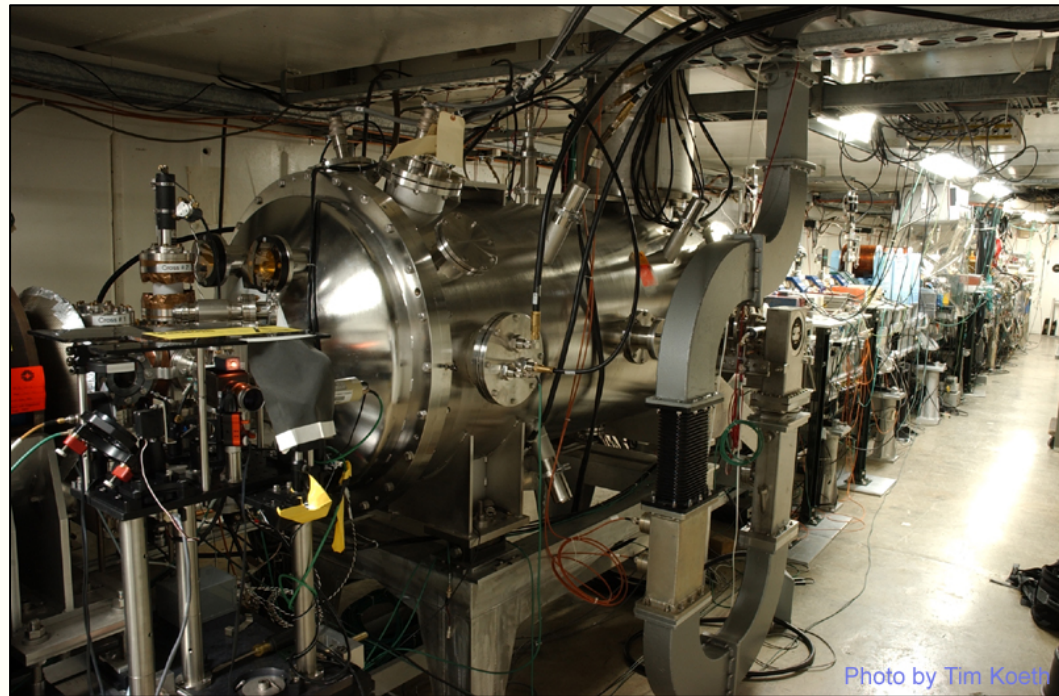


A0 Photo Injector

- The A0 Photo Injector has been in operation since late 90's and has been a training ground for SCRF technology (see Edwards talk)
- Two klystron-based RF systems power the RF Gun and Capture Cavity
- The SCRF RF Group maintains and assists with operation of these systems
- A0 RF assets will be moved to NML in 2008



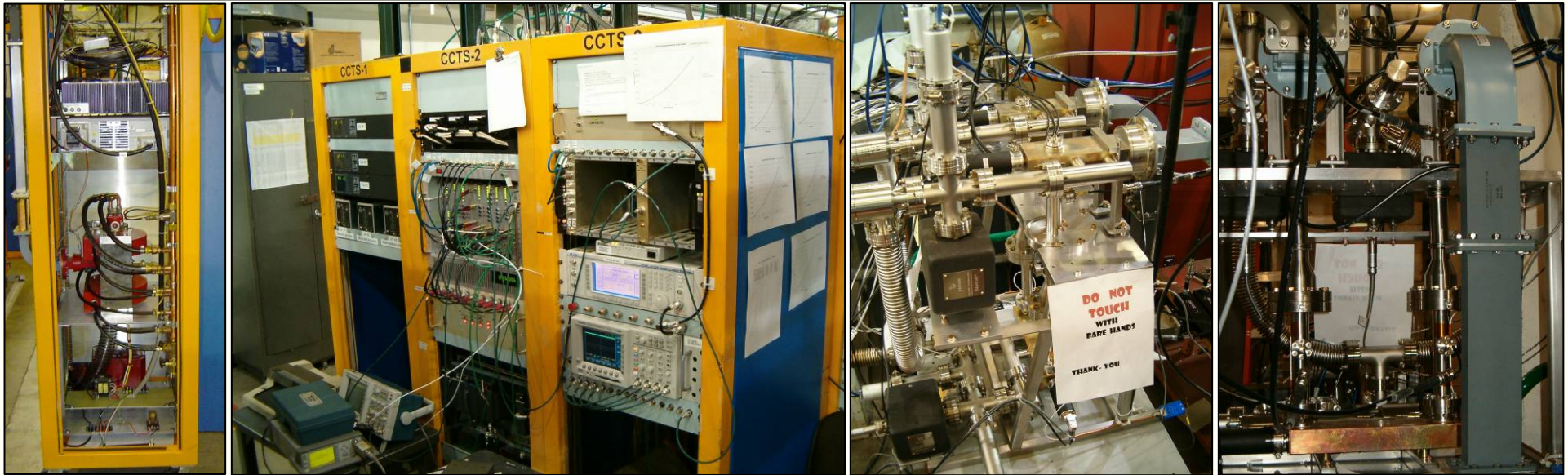
RF Gun prior to solenoid installation



Capture Cavity and beamline

Photo by Tim Koeth

Third-Harmonic RF Test Stand

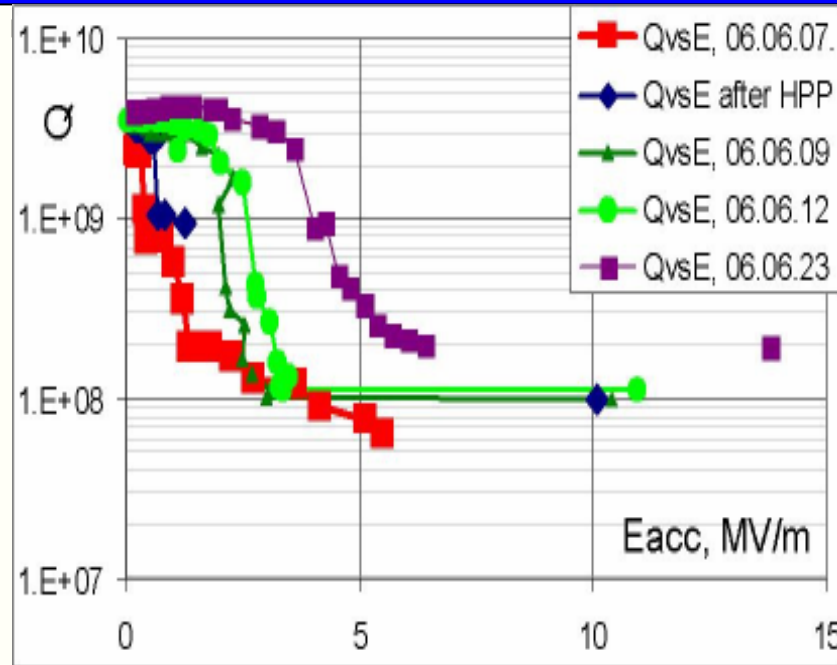


3.9 GHz, 80 kW klystron and associated racks

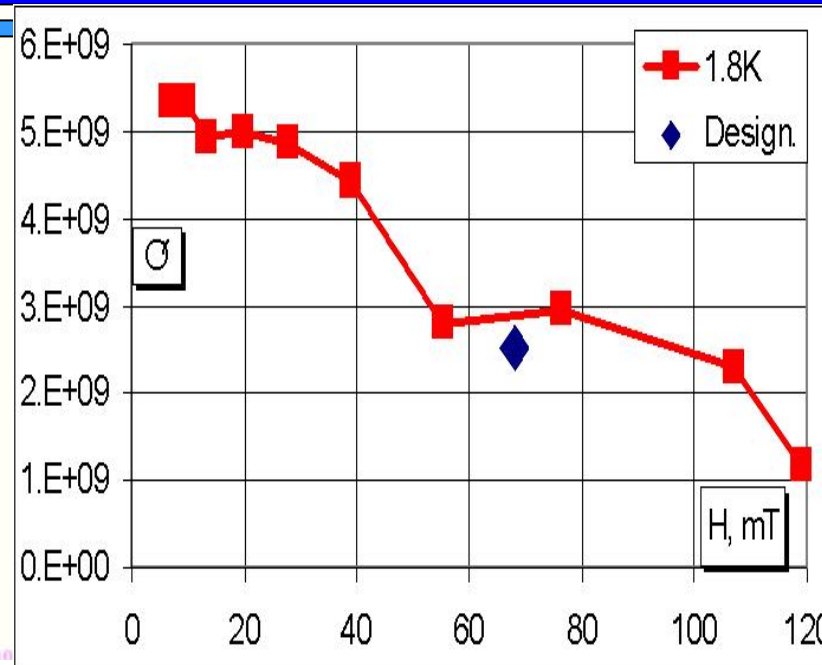
Power couplers under test

- Test stand presently located at A0 Lab where it is being used for power coupler testing and conditioning
- Will move to MDB in April to support third-harmonic cavity tests at horizontal test stand
- 2nd system will be procured and installed at NML in FY2009
- Power couplers presently tested up to 50 kW, 1 ms, 0.2 Hz

3.9 GHz Cavity Measurements

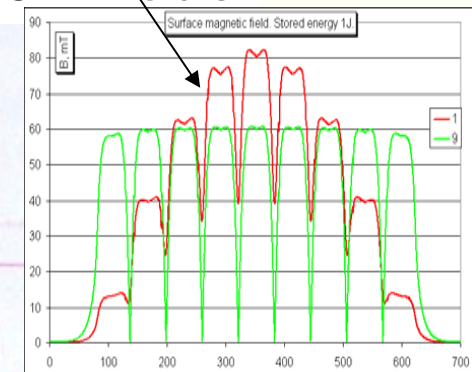
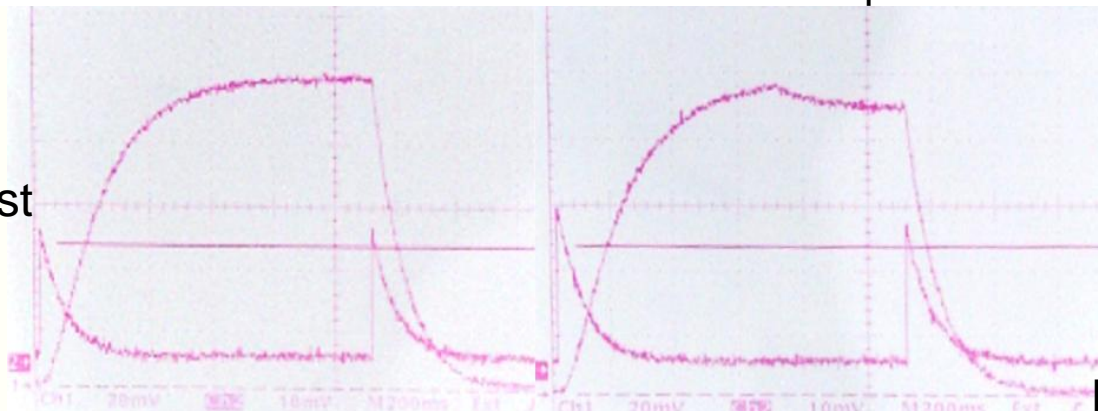


Q vs. E for π -mode



Q vs. H_{peak} for "0"-mode

MP in vertical test

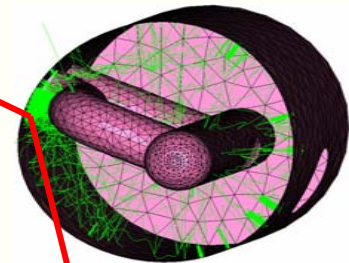
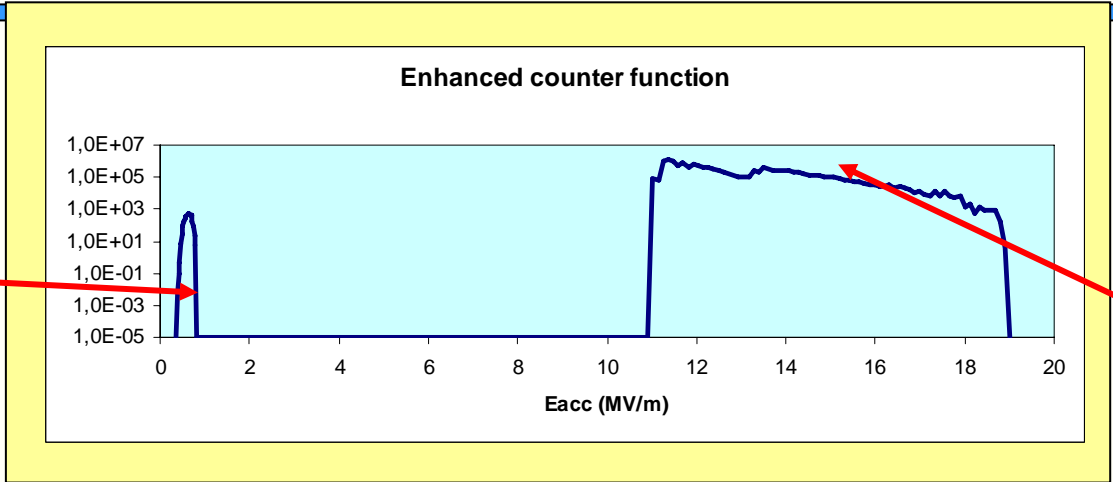
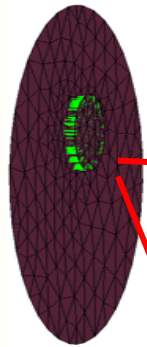


Field for 0 and π mode

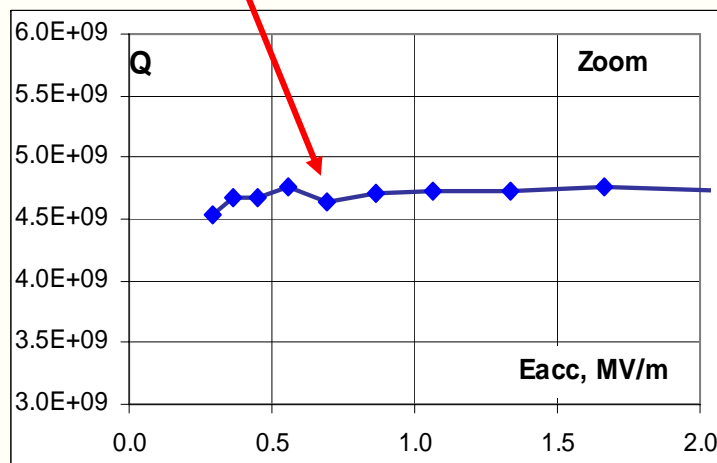
Multipacting Calculations and Measurements

3D simulation

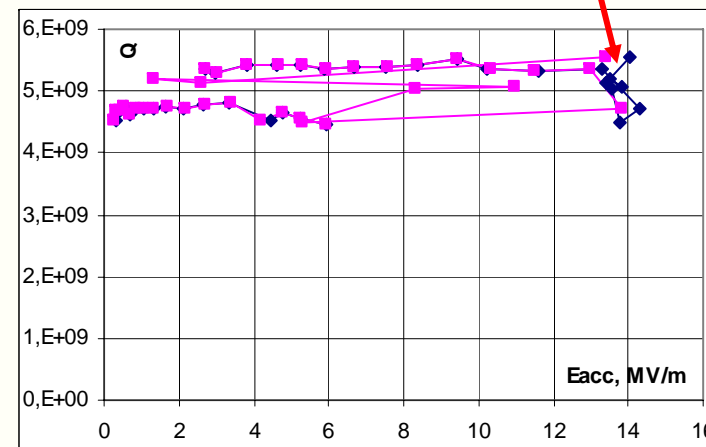
Omega 3P(Analyst)



MP in notch gap 0.6 mm



MP in 2 mm Leg-wall gap



Results of vertical test MP observed at Eacc~0.7MV/m (Q drop). Quench at Eacc~14MV/m. Second resonance frequency of HOM was tuned higher than designed value.

RF Collaborations



- **Worked with ILC collaborators to produce ILC RDR chapters**
 - **Low-Level RF (LLRF), Controls, Modulators, Klystrons, RF Distribution**
- **Working with JLab on Vertical Test Facility at IB1**
- **Working with SLAC on High-Level RF (HLRF) and modulator for the ILC Test Accelerator at New Muon Lab**
- **Working with DESY LLRF and HLRF teams**
 - **Information exchange, short term changes of station, LLRF hardware exchange**

RF R&D Issues

- 10 MW multi-beam klystrons
- RF distribution
- High-voltage modulators
- LLRF controls
- HOM couplers

FY07 RF Deliverables



- **Move 3.9 GHz, 80 kW klystron from A0 to Meson, commission, and support horizontal tests of third-harmonic cavities.**
- **Connect 1.3 GHz, 300 kW klystron at Meson to horizontal test stand, commission, and support cavity testing.**
- **Install and commission 1.3 GHz, 300 kW klystron at NML for Capture Cavity II**
- **Install and commission 1.3 GHz, 5 MW klystron at NML for first cryomodule**
- **Support commissioning and testing at IB1 Vertical Test Facility**
- **Perform vertical tests of 3.9 GHz cavities at A0**
 - Interpret results and guide HOM design changes
- **Perform RF measurements, calculations and tuning in support of 1.3 and 3.9 GHz activities**

Required Funding



Infrastructure	M&S	SWF	Total with Indirect	RF Portion
Cavity Fabrication Infrastructure	\$ 3,000	\$ 675	\$ 4,380	\$ -
Cavity Processing Facilities	\$ 11,100	\$ 4,590	\$ 18,945	\$ -
Vertical Test Stand (VTS 2 & 3)	\$ 2,625	\$ 1,845	\$ 5,475	\$ 93
Horizontal Test Stand (HTS 2)	\$ 1,220	\$ 1,057	\$ 2,805	\$ 1,096
Cavity/Cryomodule Assembly Facilities (CAF_MP9 & ICB)	\$ 690	\$ 270	\$ 1,158	\$ -
NML Facility (ILCTA_NML)	\$ 18,270	\$ 23,220	\$ 51,700	\$ 10,943
Cryogenics for Test Facilities	\$ 10,690	\$ 950	\$ 13,692	\$ -
Cryomodule Test Stand	\$ 5,400	\$ 2,970	\$ 10,180	\$ 1,558
Material R&D	\$ 870	\$ 722	\$ 1,960	\$ -
Illinois Accelerator Research Center	\$ 20,000	\$ 4,050	\$ 28,605	\$ -
Grand Total (\$k)	\$ 73,865	\$ 40,349	\$ 138,900	\$ 13,690

- **Required RF funding is ~10% of total**
- **NML RF cost split: 47% LLRF and 53% HLRF**
- **10 MW multi-beam klystron, waveguide distribution, and Marx modulator provided by SLAC, i.e., not included in FNAL required funding.**

Conclusions

- **The SCRF RF Group is supporting ongoing SCRF activities and planning for future activities**
- **This is being accomplished through inter-divisional collaboration and work assignments**
- **We will continue our national and international collaborations on SCRF issues**
- **We will engage in ILC EDR activities**
- **We will accomplish this work as a team working together toward common goals**