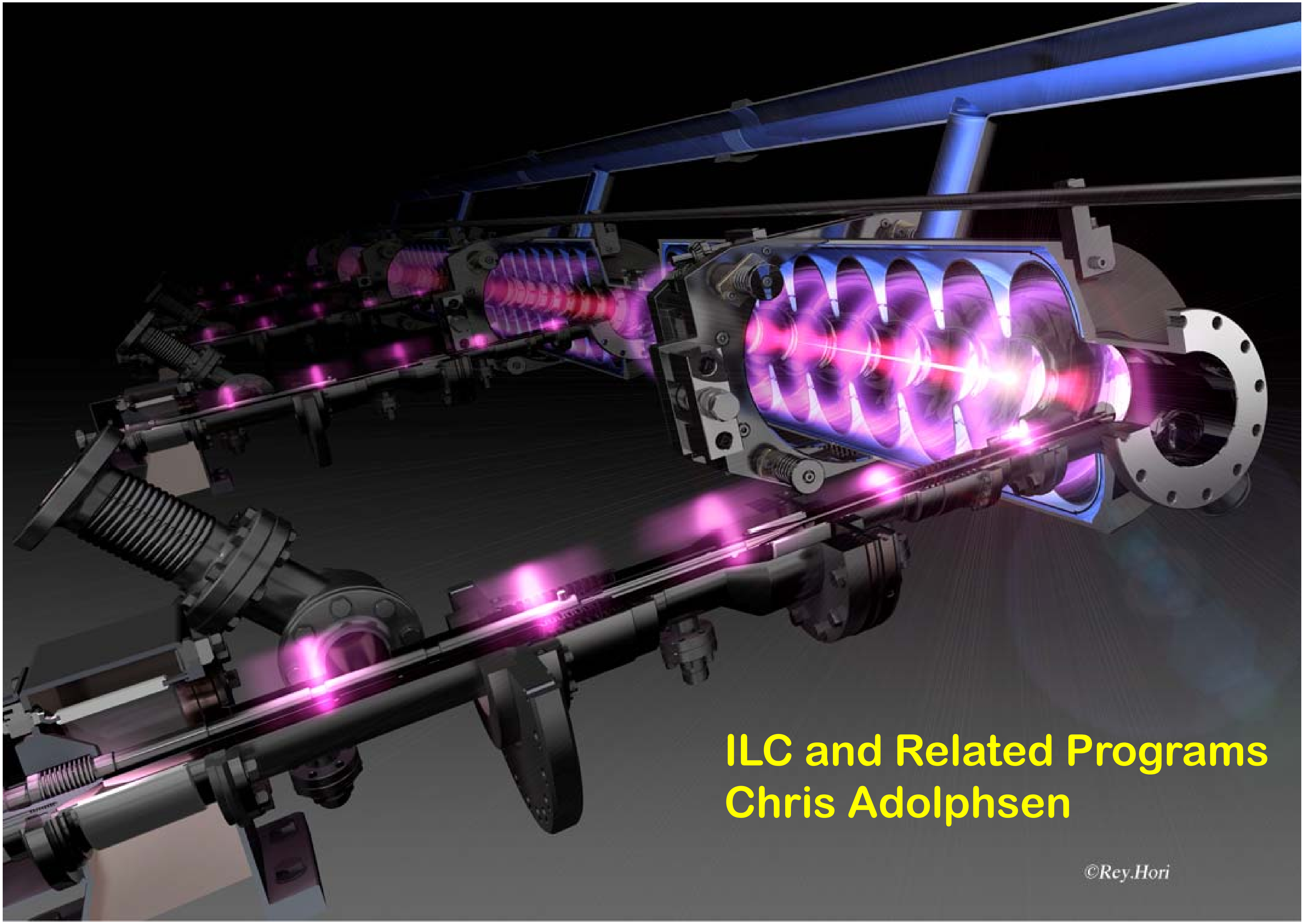
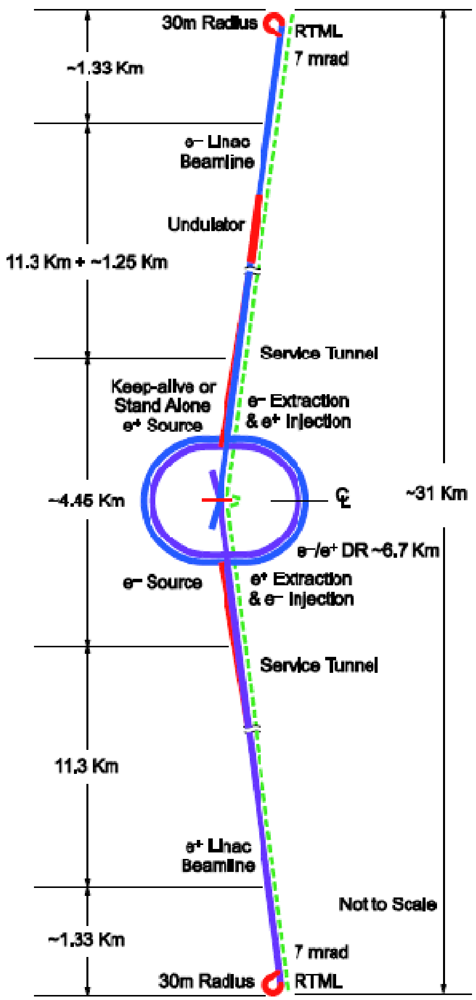


ILC and Related Programs

Chris Adolphsen

ILC Overview

RDR ILC Layout

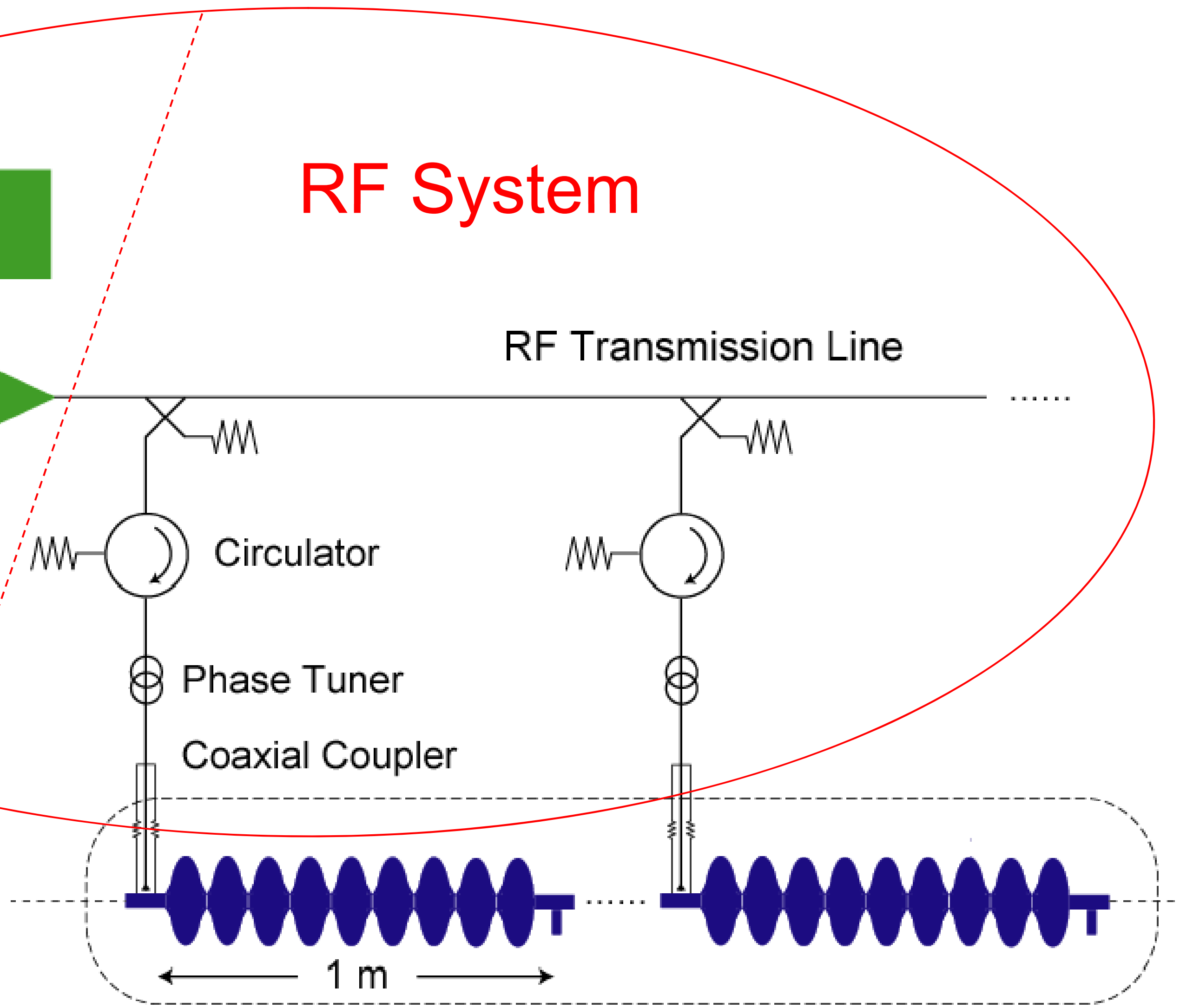


- Design fairly mature – aiming for a TDR at end of 2012 with updated costs
- In 2009, proposed changes to the 2006 RDR design to reduce costs 10-15%, including
  - Single Linac Tunnel in combination with a more reliable RF distribution scheme
  - Halve the number of bunches per pulse
  - Halve the damping ring size
  - Consolidate the central region tunnels
- Advisory group rejected wholesale adoption of these changes - currently reviewing each one with expanded oversight by HEP community

SLAC ILC Program

- FY10 budget ~ 12 M$ with about half for HLRF. Includes:
- High Level RF (HLRF) development
  - Marx Modulator
  - Sheet Beam Klystron
  - Klystron Cluster Scheme (KCS) for rf distribution
  - Local rf distribution (also supports FNAL NML program)
  - Cavity power couplers (also supports FNAL NML program)
- Electron Source - generate ILC-like bunch train
- Damping Rings
  - Electron cloud simulations and mitigation for positron ring
  - Fast kickers for the Damping Rings
- Beam Delivery System (BDS)
  - Machine-Detector Interface issues such as vibration and magnet-beam stay-clear
  - Final Focus optics tests at KEK ATF2
- Other
  - Beam physics, wakefield and operational issues in the Main Linacs
  - Global controls: adoption of the high availability ATCA crate standard

SLAC RF System Development



Goals:

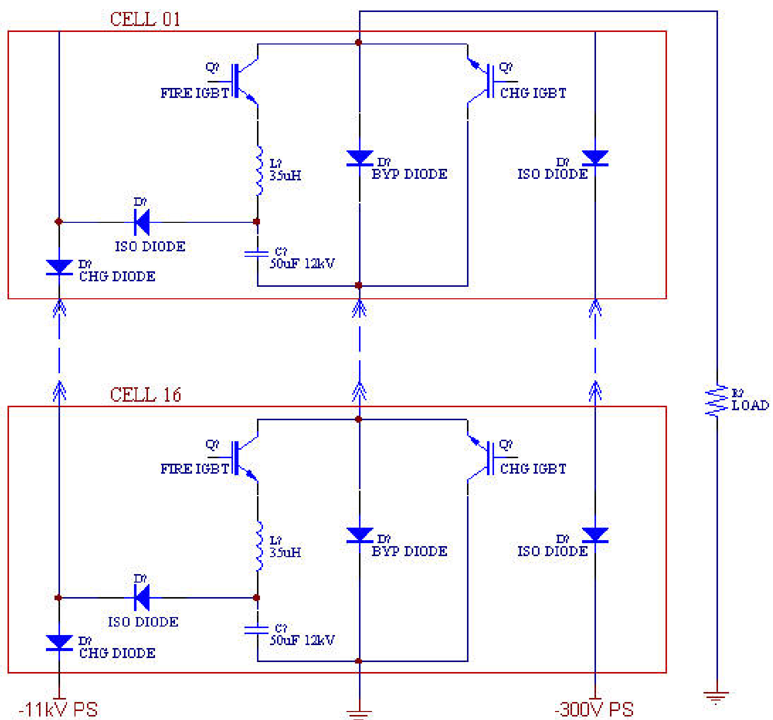
Develop more reliable and lower cost L-band RF source components

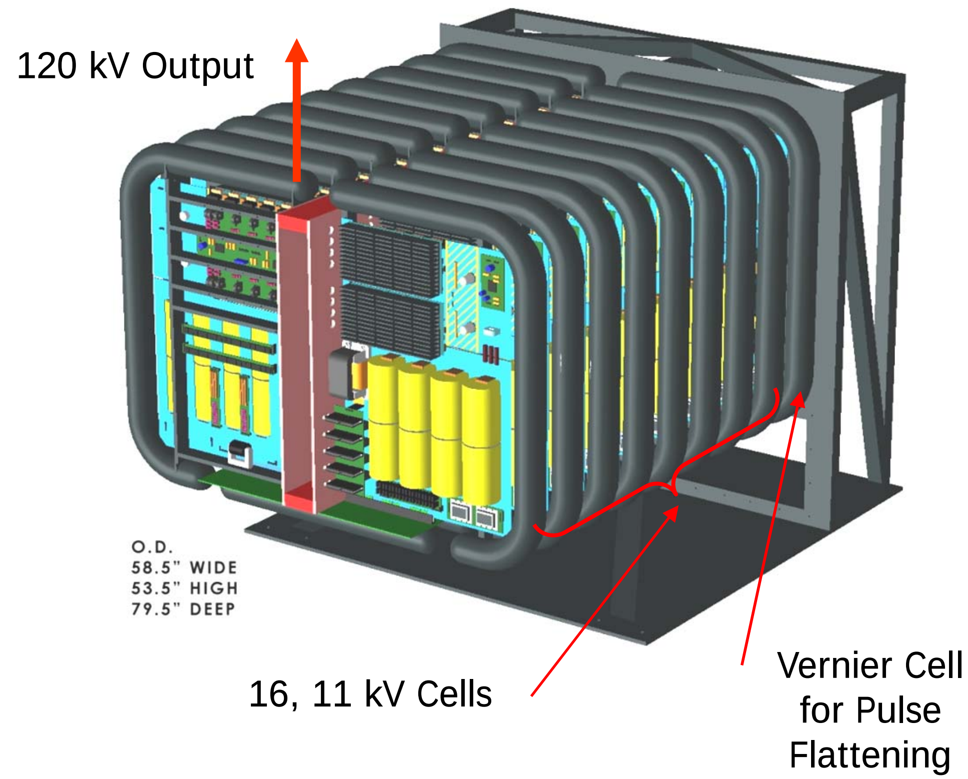
Verify performance goals of the rf system

Cryomodule 1 of 3
(9-8-9 Cavities per Cryomodule)

SLAC P1 Marx Modulator

(120 kV, 140 A, 1.6 ms, 5Hz)

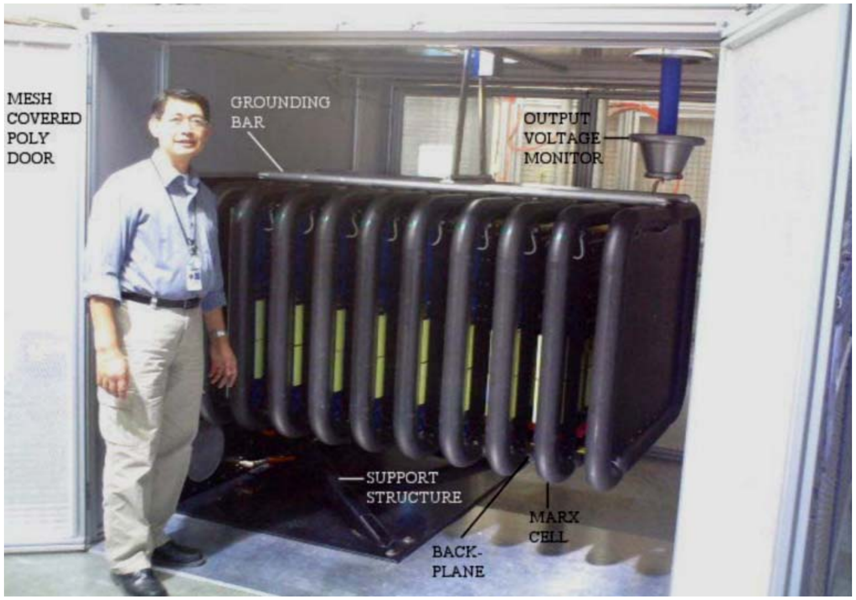


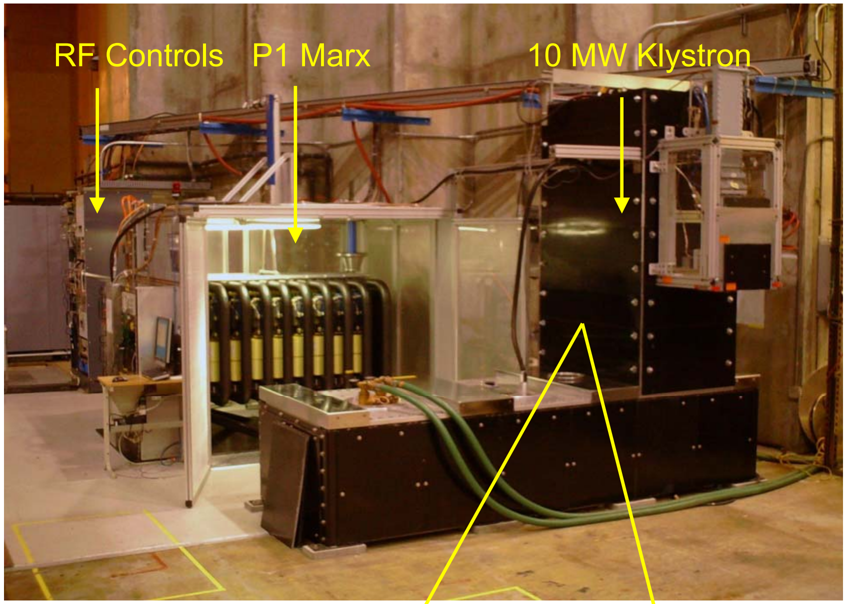


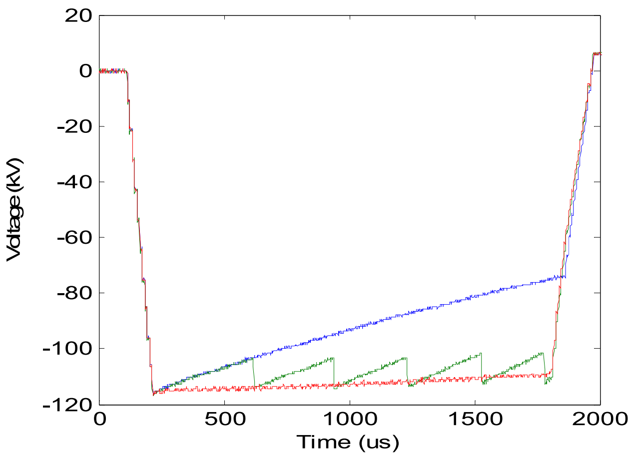
- 11 kV per cell (11 turn on initially, 5 delayed for coarse droop compensation)
- Switching devices per cell: two 3x5 IGBT arrays
- Vernier Cell (‘Mini-Marx’) flattens pulse to 1 kV

Marx Modulator and 10 MW MBK at ESB

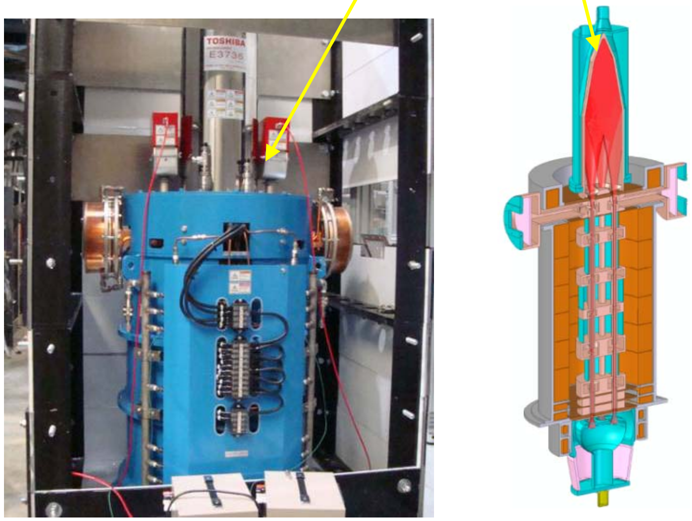
More than 2000 Hours of Operation







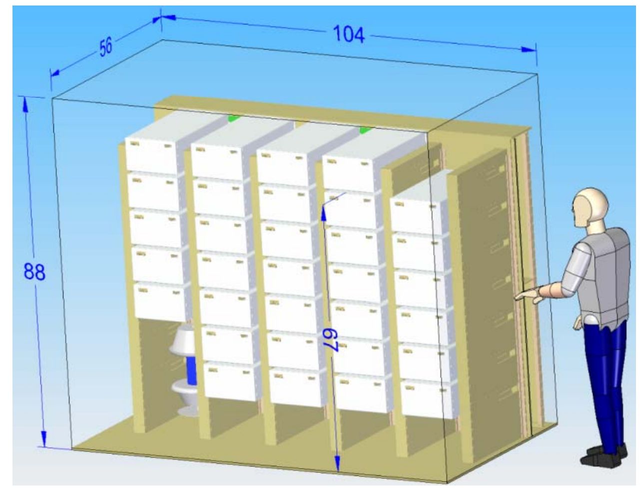
Modulator Voltage with Different Levels of Droop Compensation

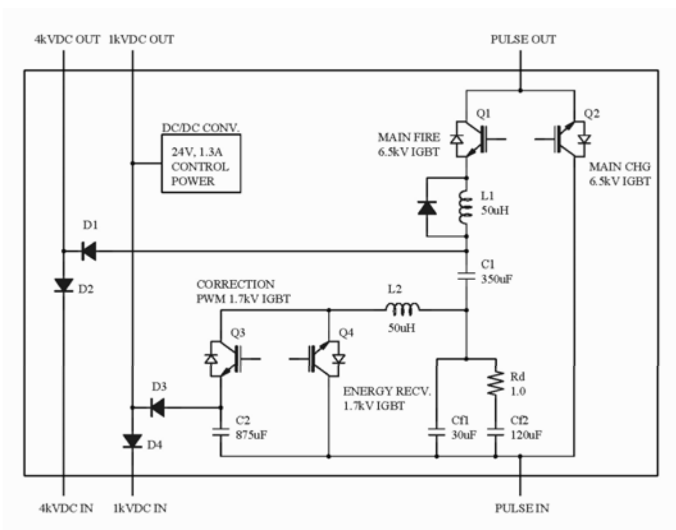


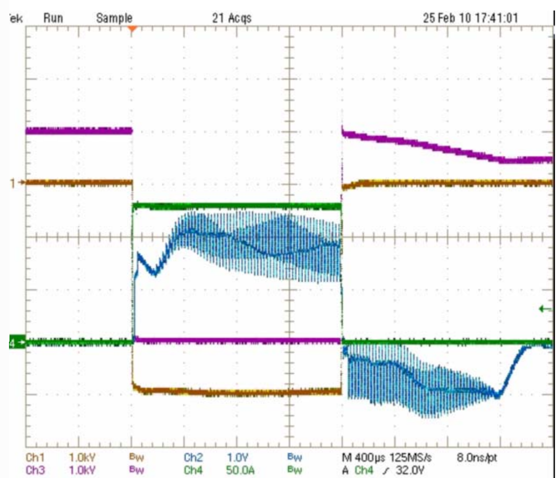
Toshiba 10 MW Multi-Beam Klystron (MBK)

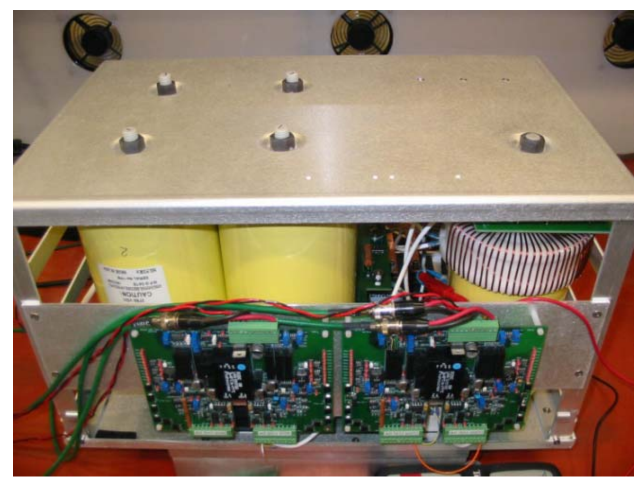
Evolution to the P2-Marx

- 2nd Generation design builds on P1 experience
- Improved high availability architecture
  - Truly modular topology; single repeated cell design
  - Droop compensation (via PWM) integrated into each cell
  - 4 kV cell voltage eliminates series switch arrays
- Prototype cell undergoing testing
- Expected completion in FY11



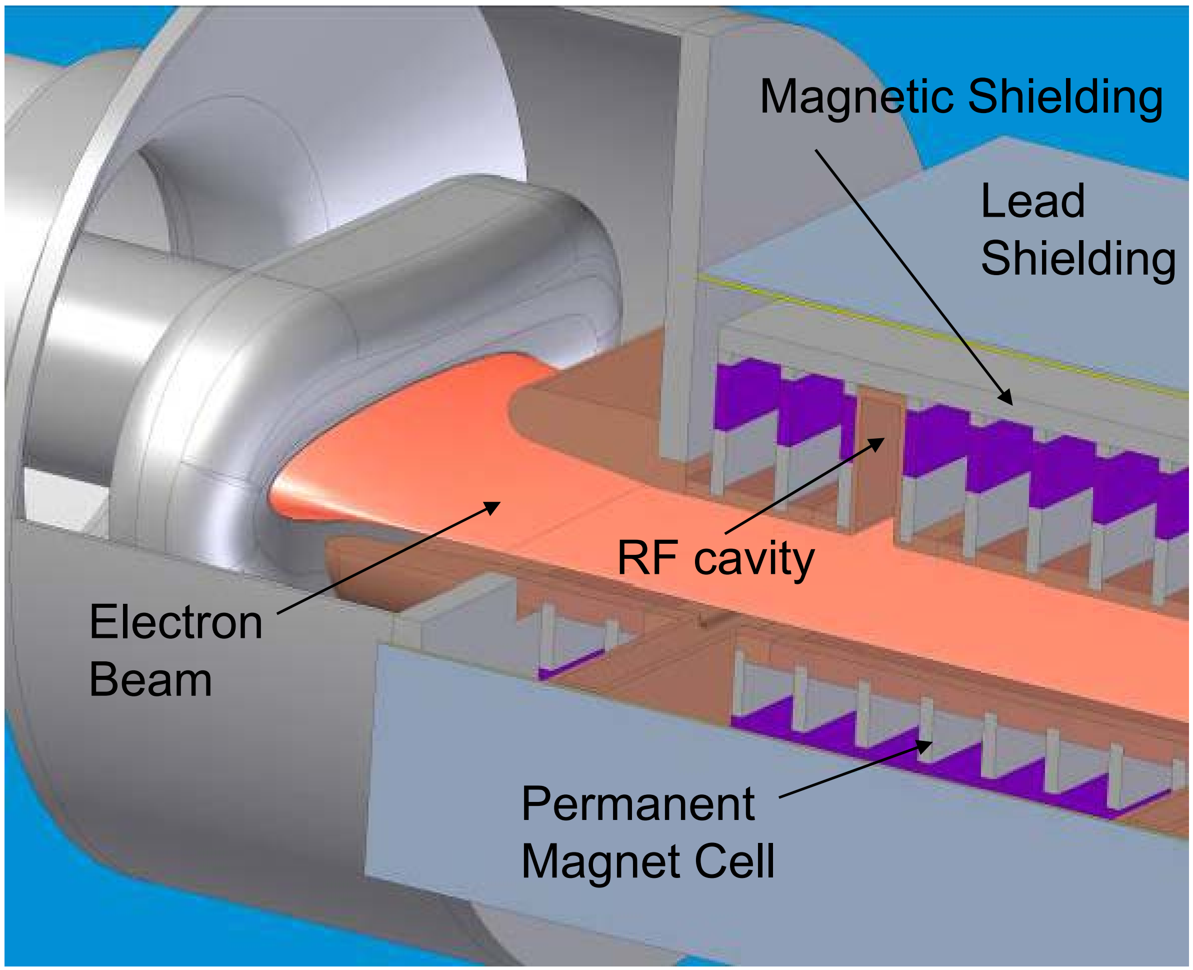




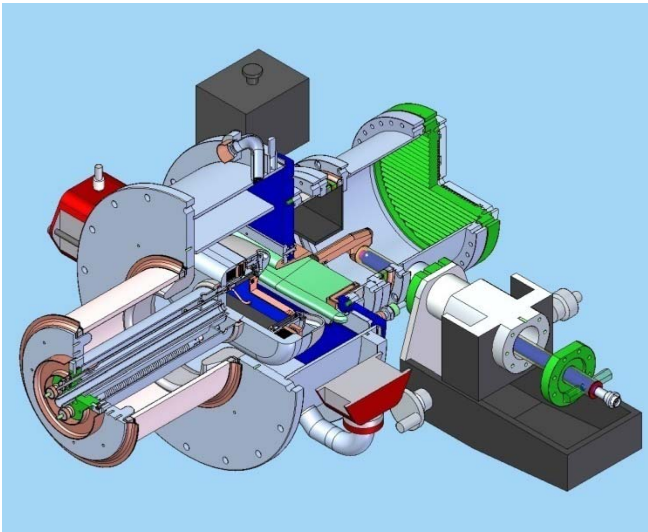


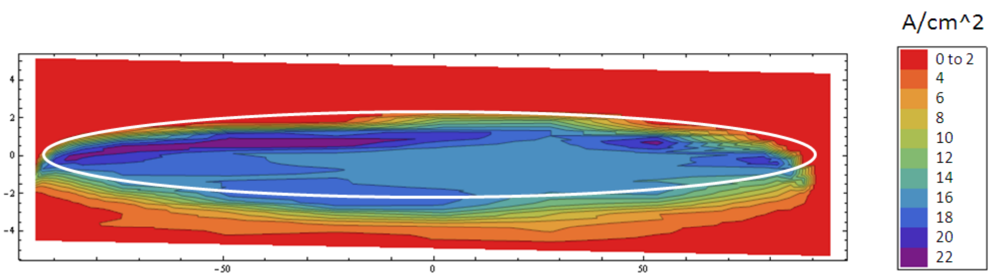
Sheet Beam Klystron Development

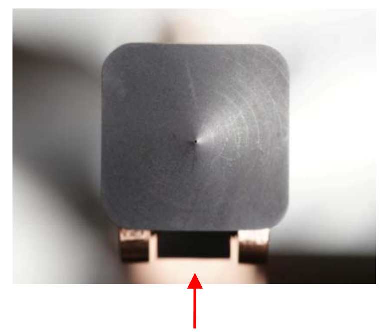
An elliptical beam is focused in a periodic permanent magnet stack that is interspersed with rf cavities – gives same high efficiency (65%) as multiple beams but less expensive with use of permanent magnet focusing



Beam Tester Results





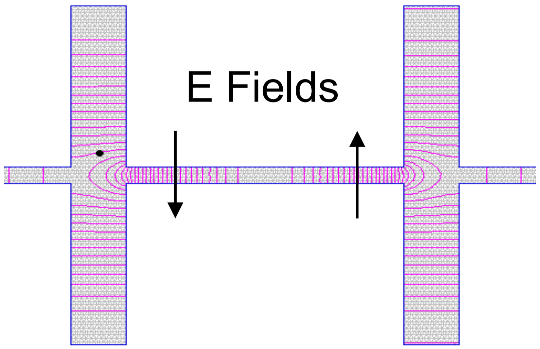


During the tests, ran very low pulse rate as ‘sputtered’ carbon from the beam probe shield poisoned the cathode.

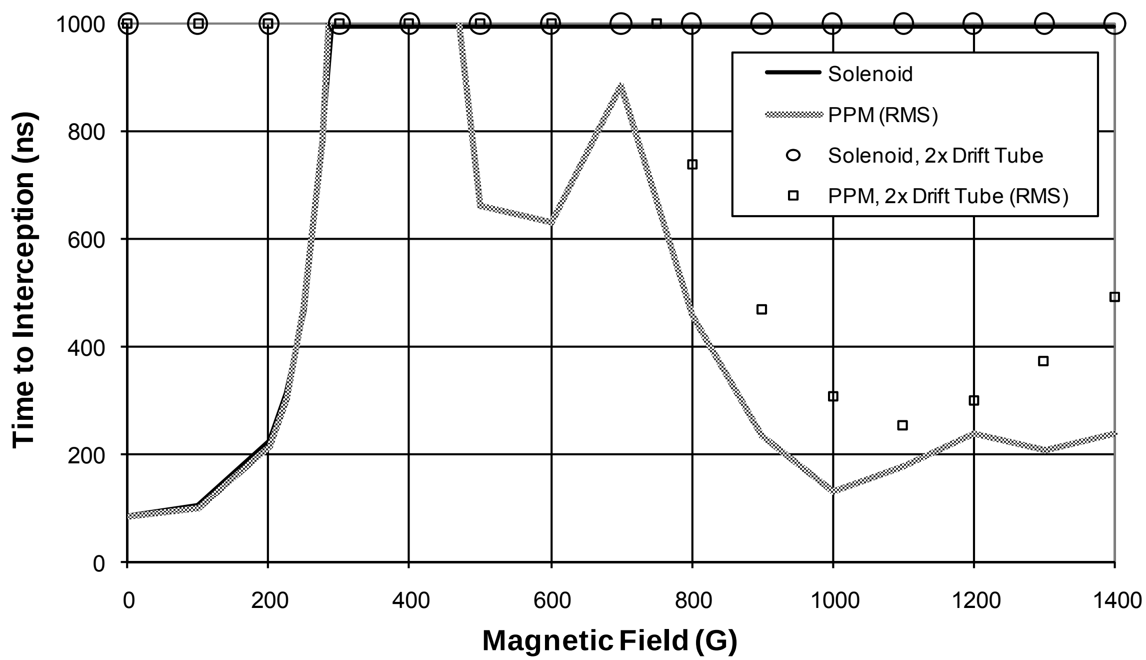
A vertical asymmetry was observed in the measured current density profile that was partially corrected using a 900V and 0V bias on the upper and lower focus electrodes, respectively The resulting current density is shown above - an ideal elliptical beam profile outline is superimposed in white.

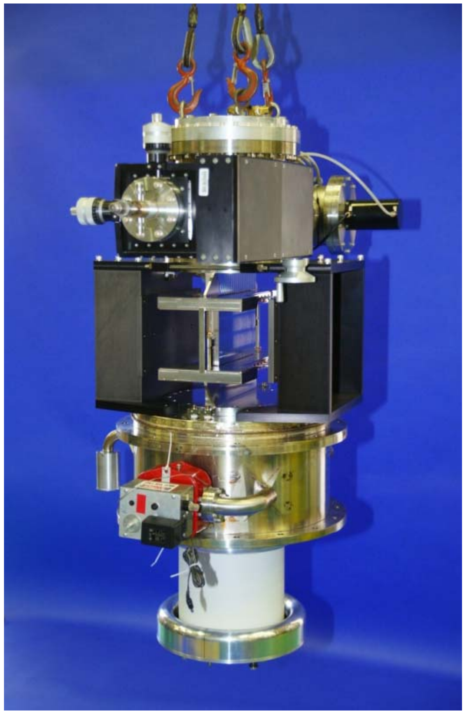
Two-Cavity Stability Test

Found no simple means to suppress the modes in simulation without doubling the drift tube height to decrease cavity coupling and a using solenoidal magnet to increase the focusing strength.



Built a two-cavity oscillation device that will be used to verify the predicted regions of stability vs magnetic field. Stop further work as developing a solenoid-focused SBK would extend beyond the ILC TDR timescale.

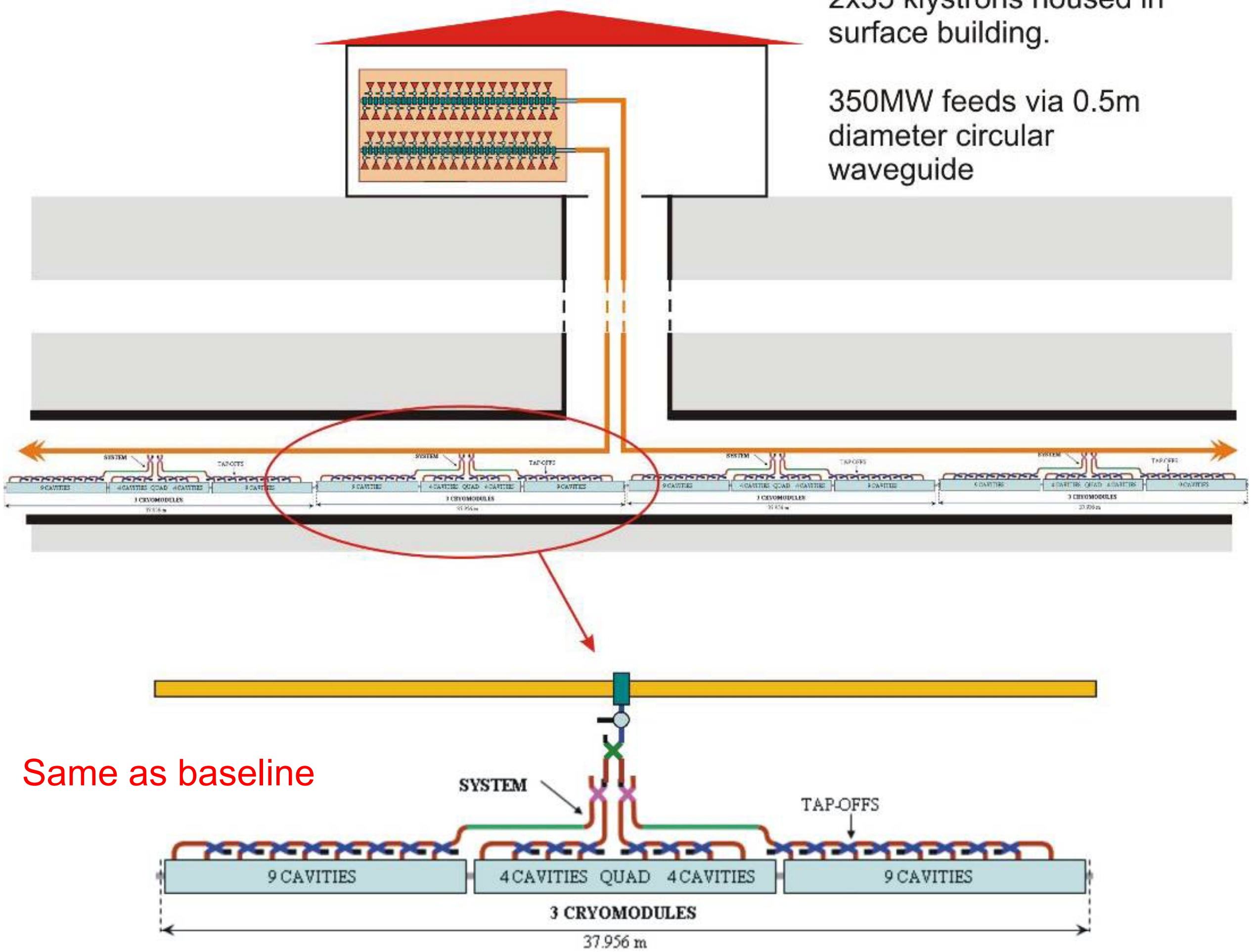




Klystron Cluster Concept

2x35 klystrons housed in surface building.

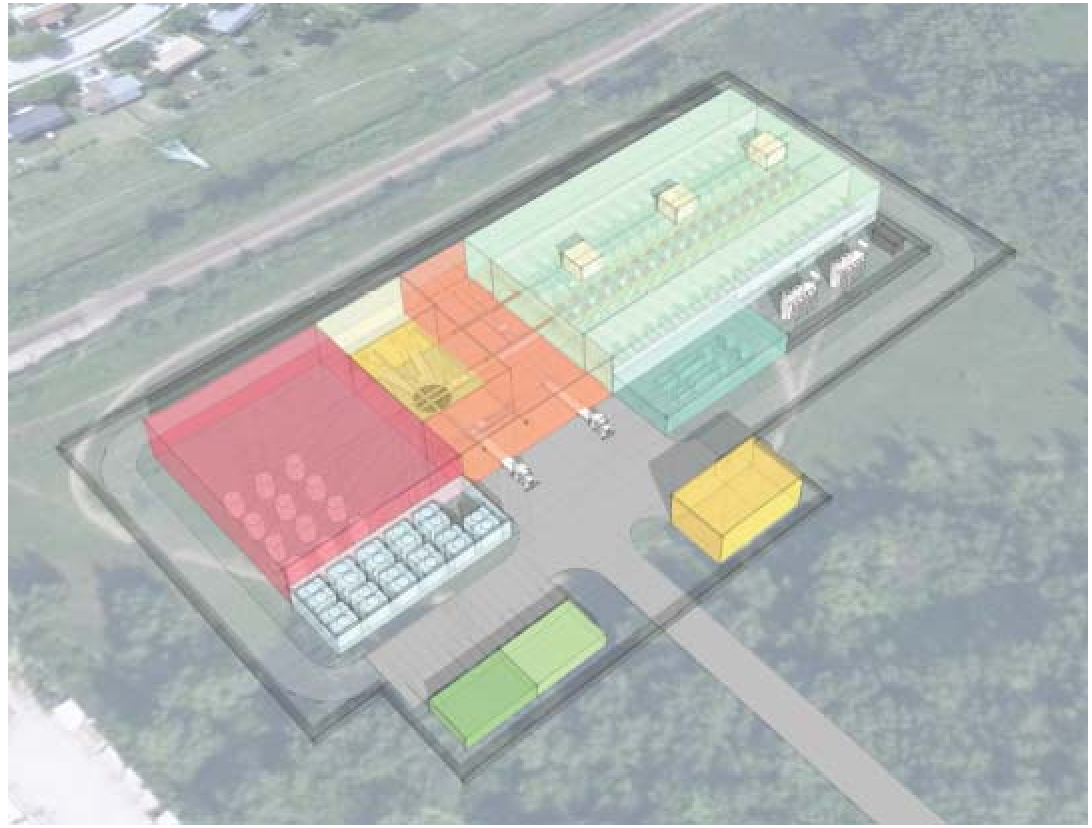
350MW feeds via 0.5m diameter circular waveguide

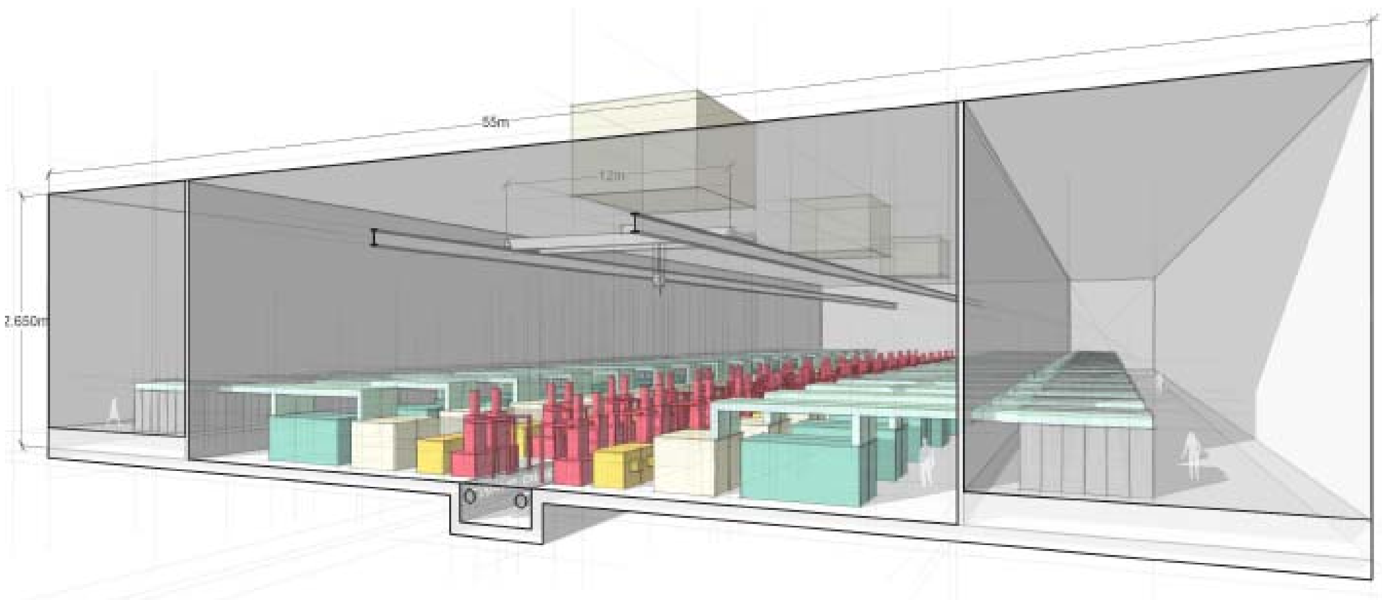


Each tap-off from the main waveguide feeds 10 MW through a high power window and probably a circulator or switch to a local PDS for a 3 cryomodule, 26 cavity RF unit (RDR baseline).

- RF power “piped” into accelerator tunnel every 2.5 km
- Service tunnel eliminated
- Electrical and cooling systems simplified
- Concerns: power handling, LLRF control coarseness

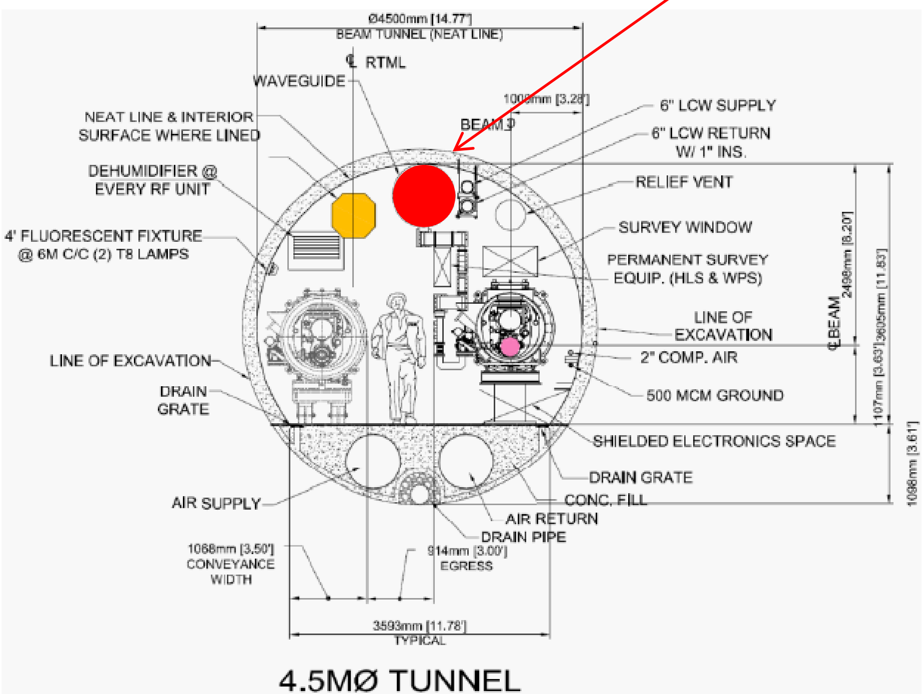
Klystron Cluster Surface Building Concepts by Holabird/Root

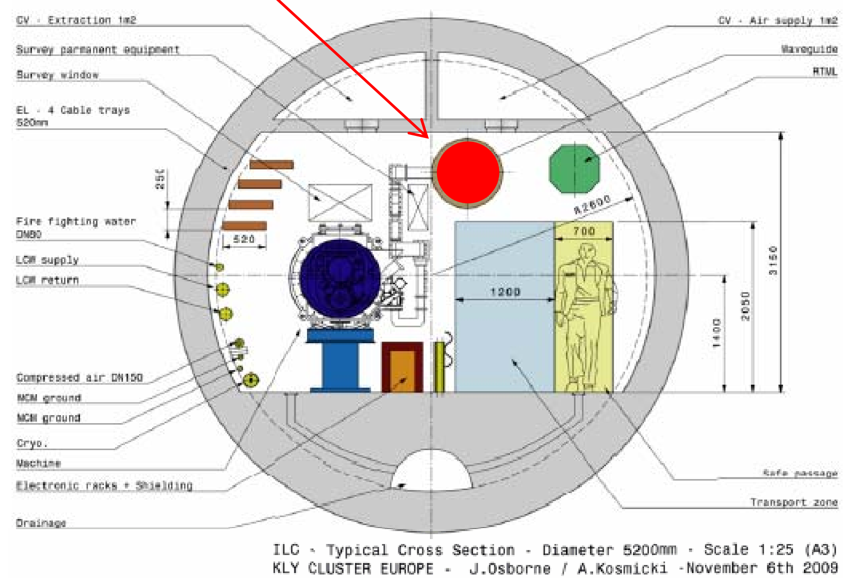




Single Tunnel Layout with KCS

RF Waveguide

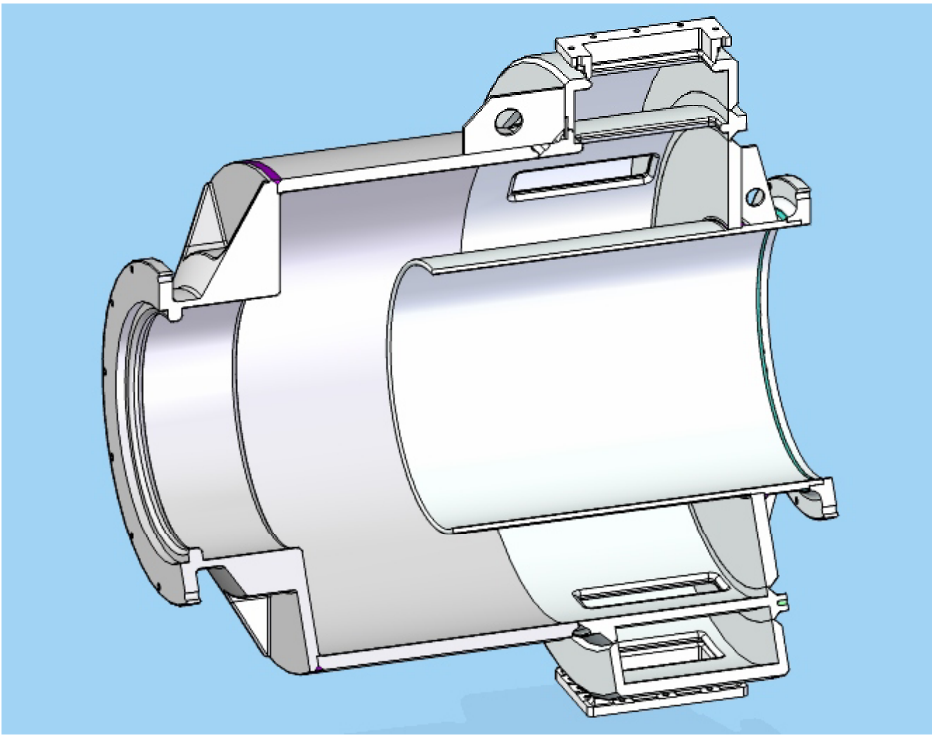


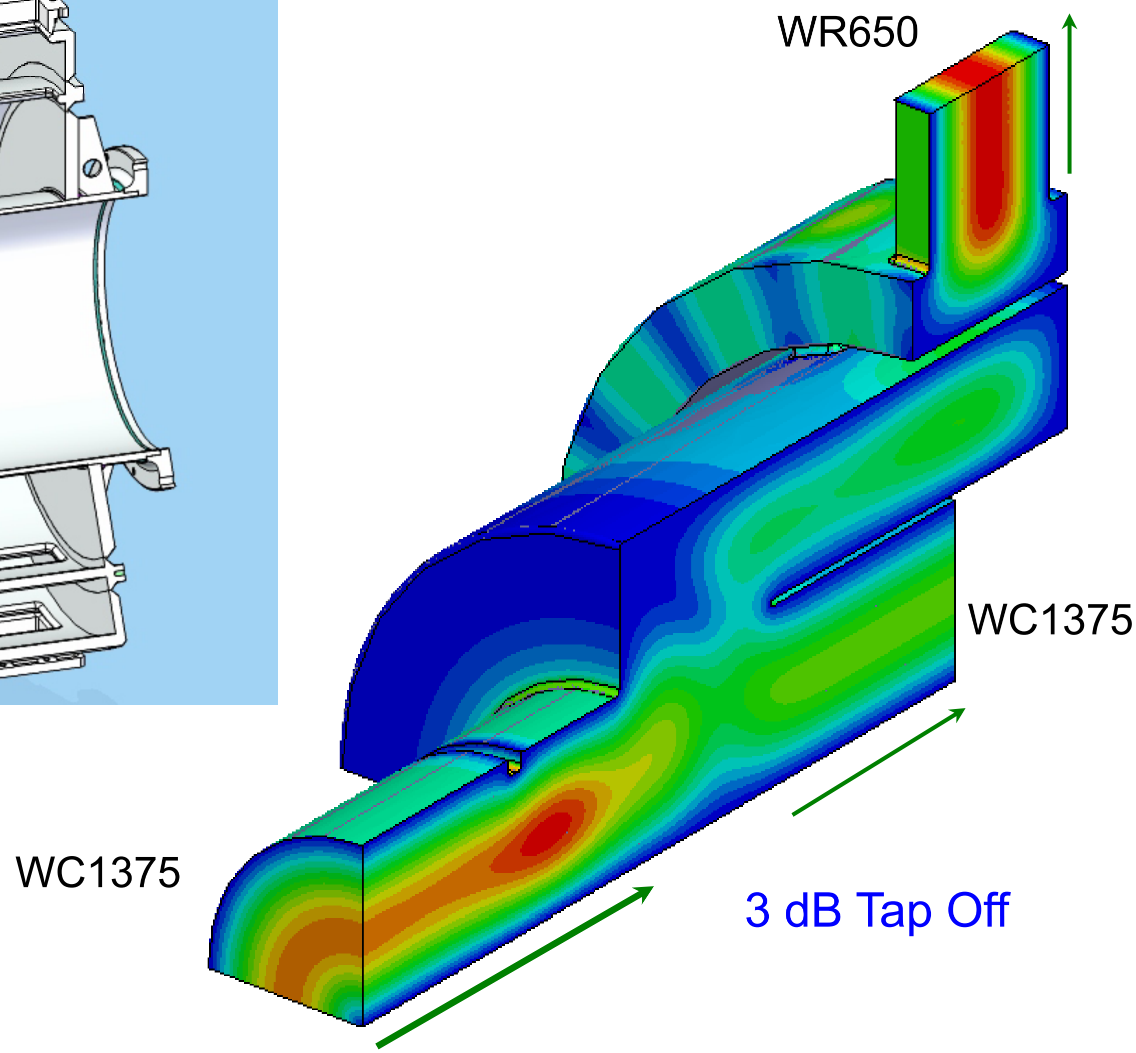


Americas Region

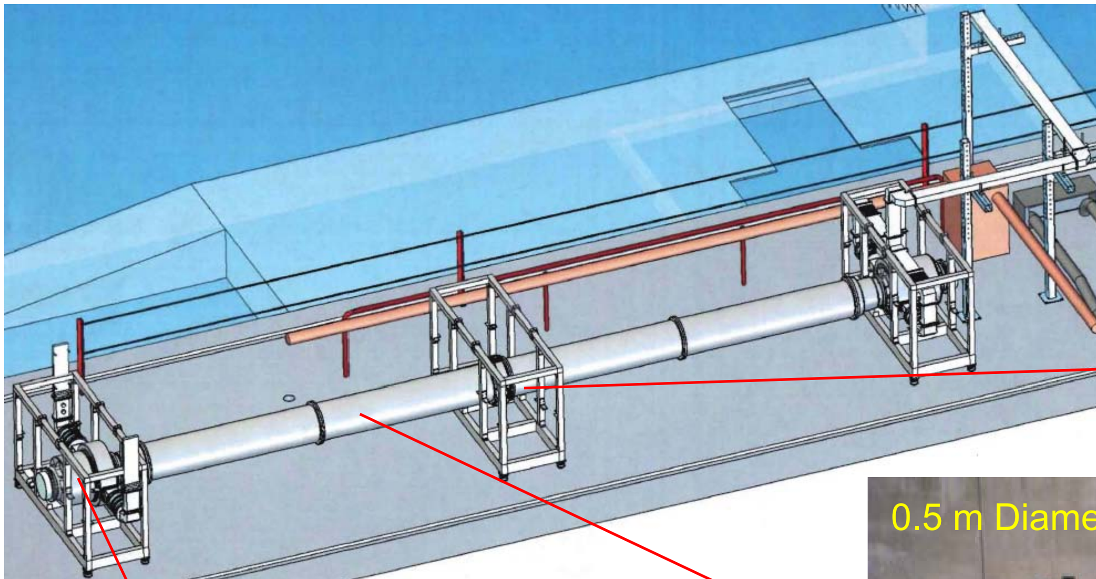
European Region

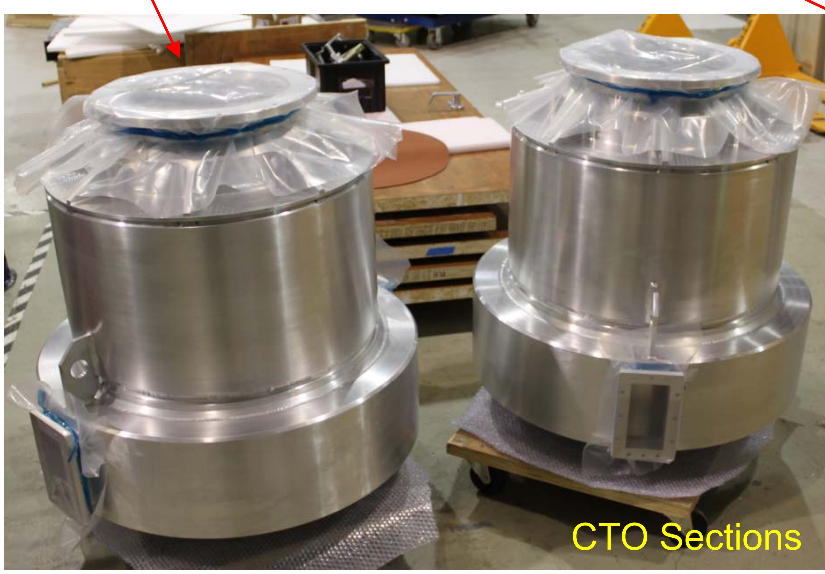
Coaxial Tap Off (CTO)





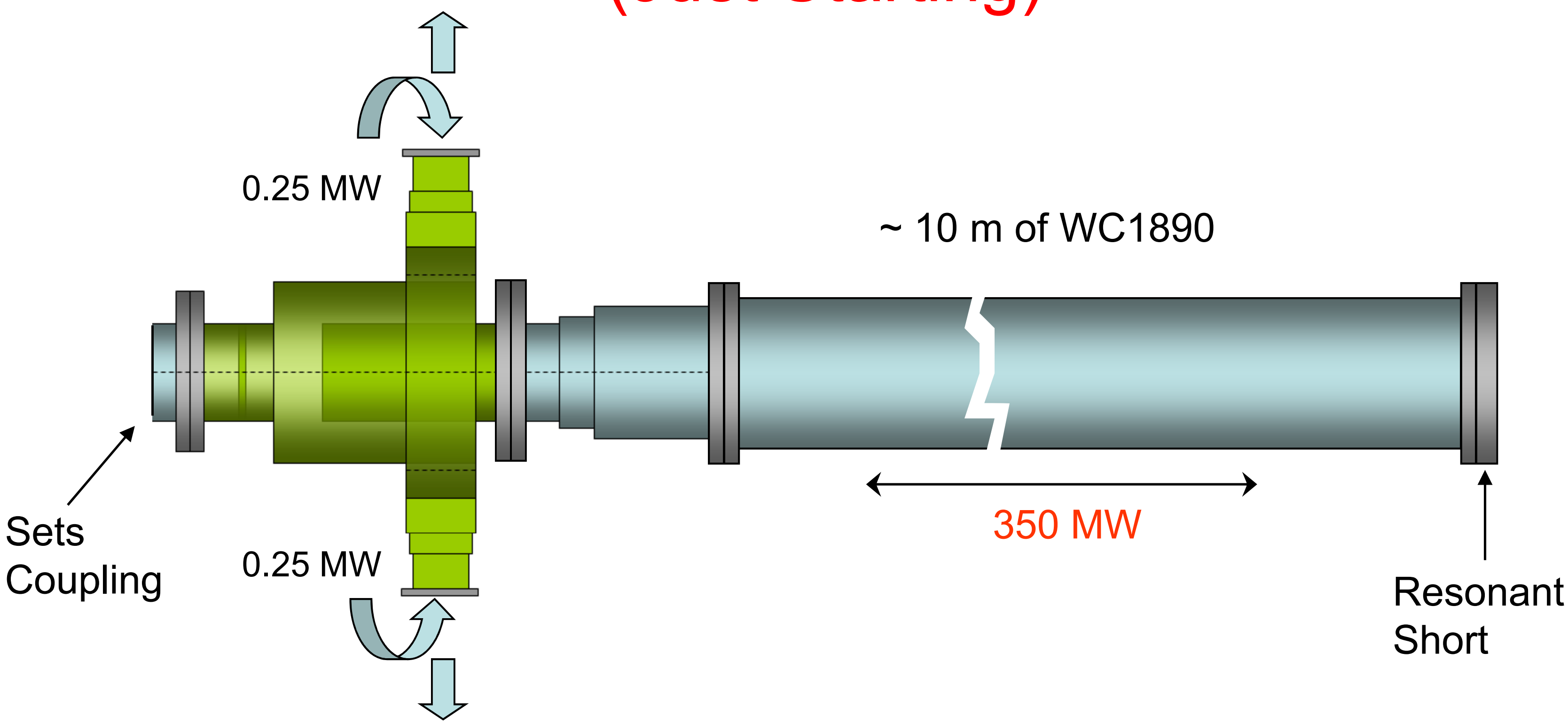
KCS Test Bed at SLAC ESB





Phase I Demonstration

(Just Starting)

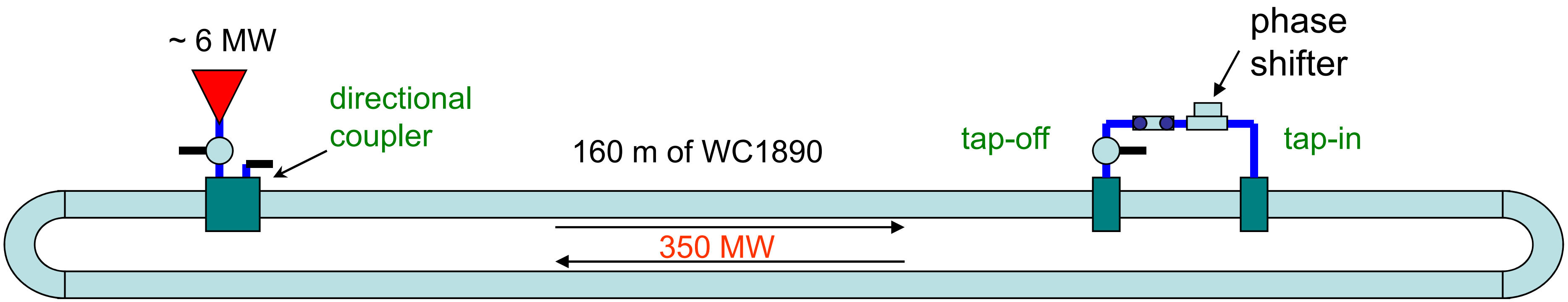


Adjusted input coupling (beta = 3) and will resonantly charge the line (tau = 8 us) to field levels equal to those for 350 MW transmission (requires only 0.5 MW of klystron power). Do this under pressure (2 bar absolute) and under vacuum (< 1e-6 Torr).

Phase II Demonstration

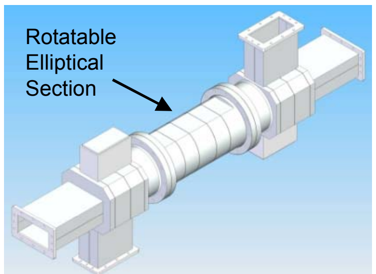
(To Be Completed in 2012)

Develop bends and configure a 160 m resonant ring to test them and a final design tap-in/off. Stored energy is about 1/5 of the worst case in the ILC with speed-of-light limited klystron shutoff time.

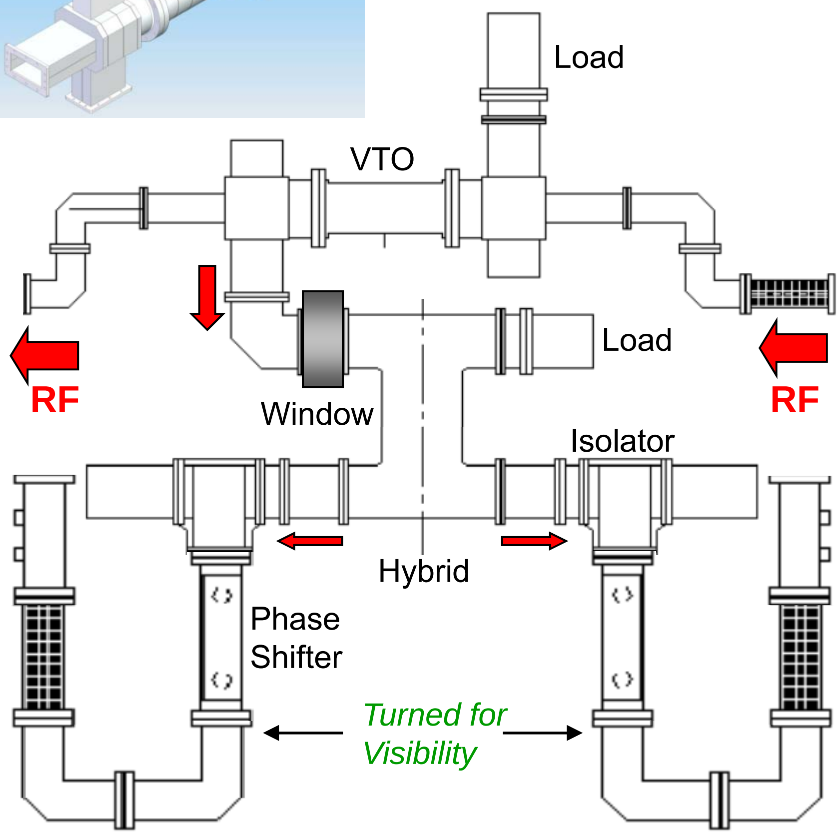


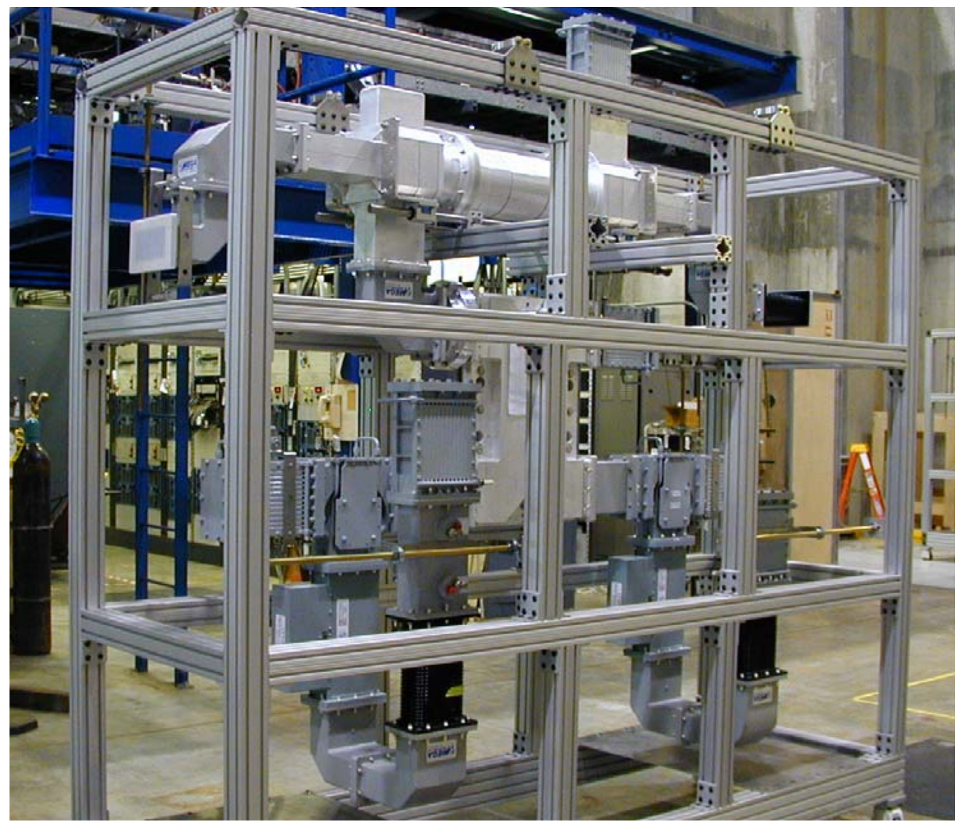
Local RF Distribution Modules

Four, two-cavity distribution modules were individually high power tested and then shipped to FNAL in FY09

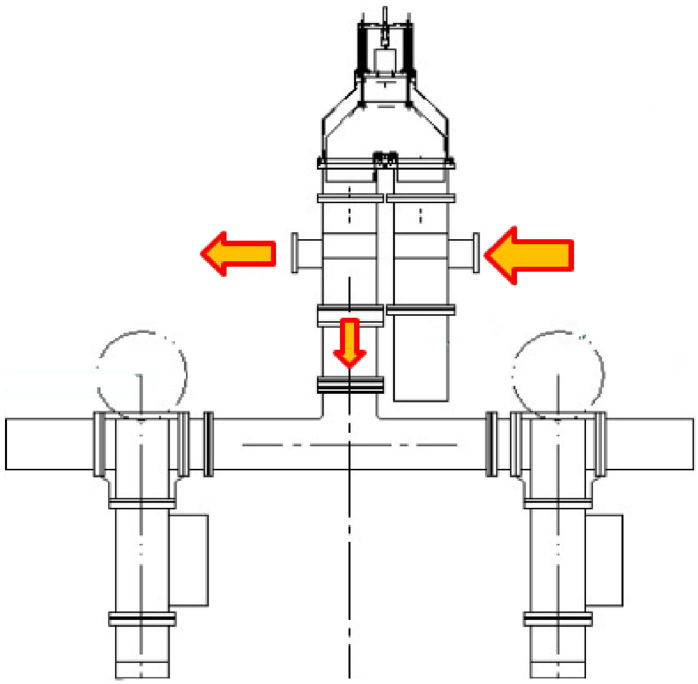


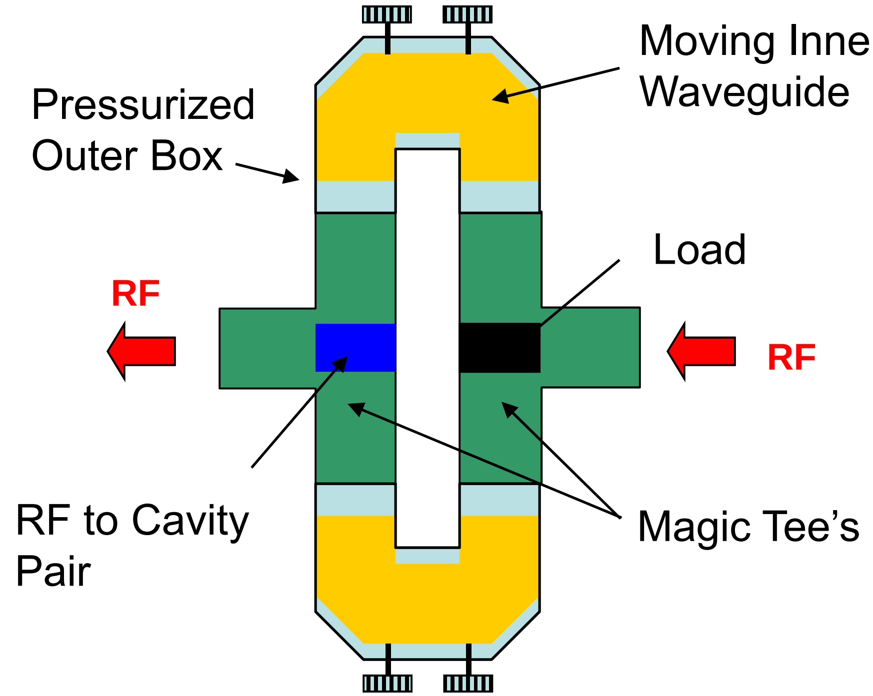
Elliptical Variable Tap-Off (VTO)

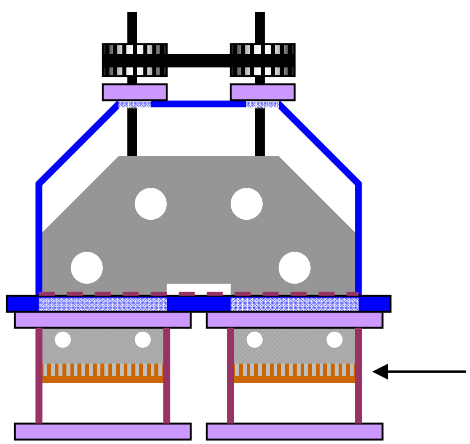




Building Simpler VTO For Next CM







Use commercial 'folded' Magic Tee's

Put remotely controllable phase shifters into U-bends – relative phase controls power split

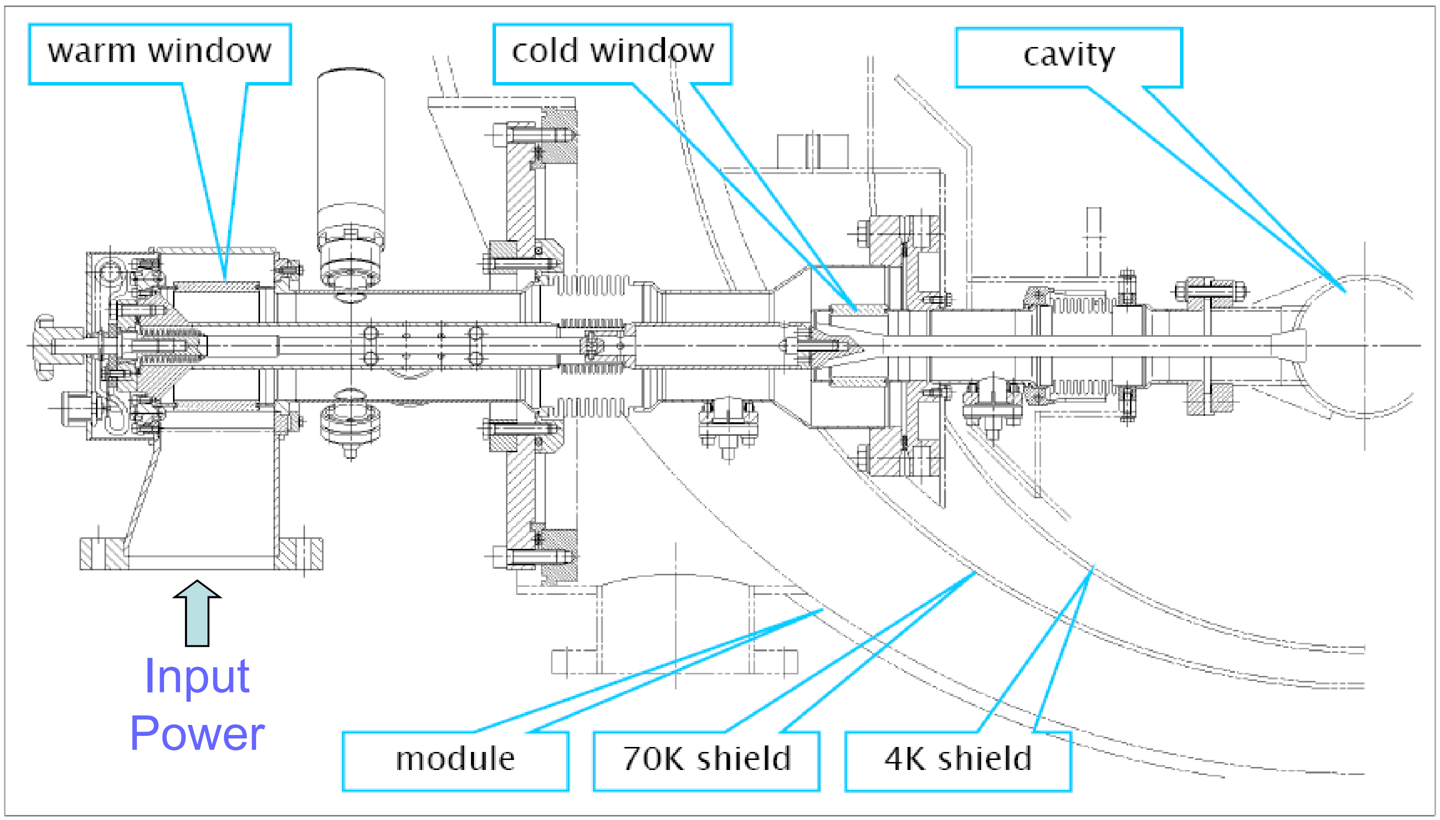
Match ideally unaffected by position

No bellows but need 'finger' stock to cut off RF

TTF-3 Coupler Design

Design complicated by need for tunablity (Qext), dual vacuum windows and bellows for thermal expansion.

Coaxial Power Coupler

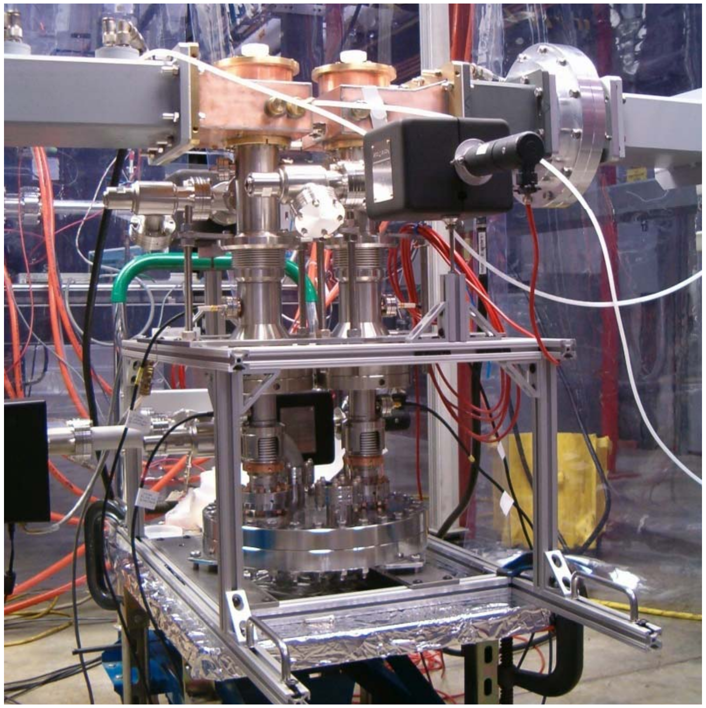


Input Power

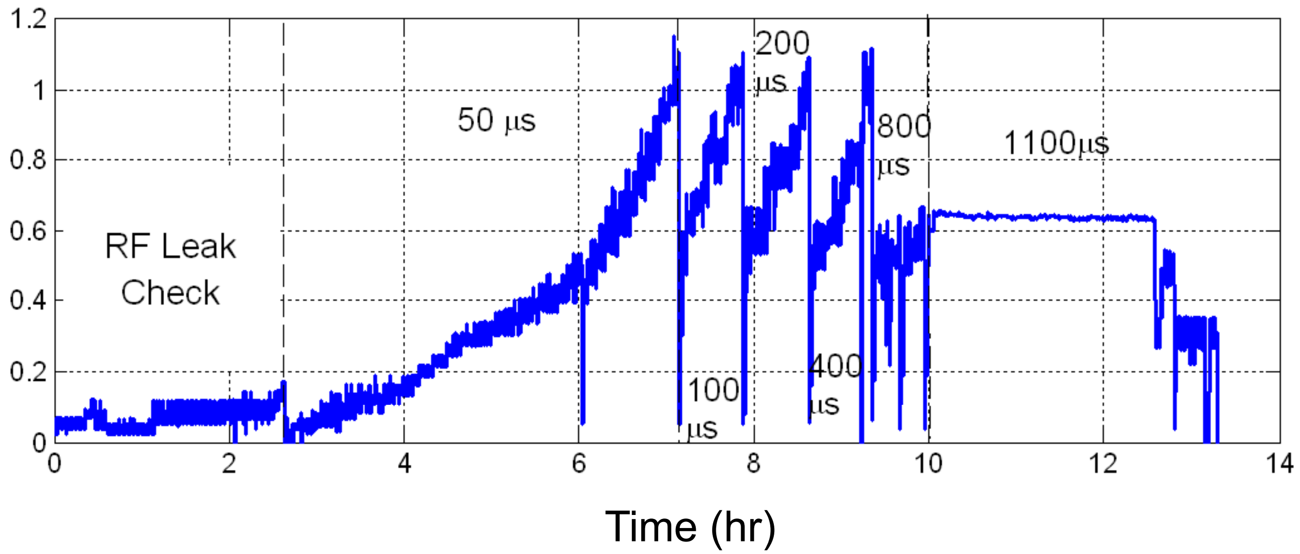
Coupler Assembly in the SLAC Class 10 Cleanroom

RF Processing of Coupler Pairs

Processing of first pair sent to FNAL:
Power (MW) -vs- Time for Pulse Widths of
50,100, 200, 400, 800, 1100 μs

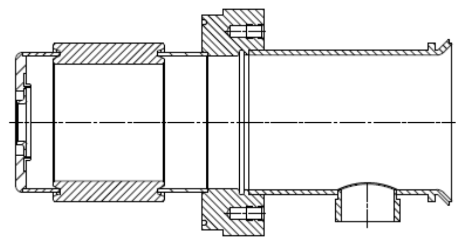


Processed Fast by Historical Standards

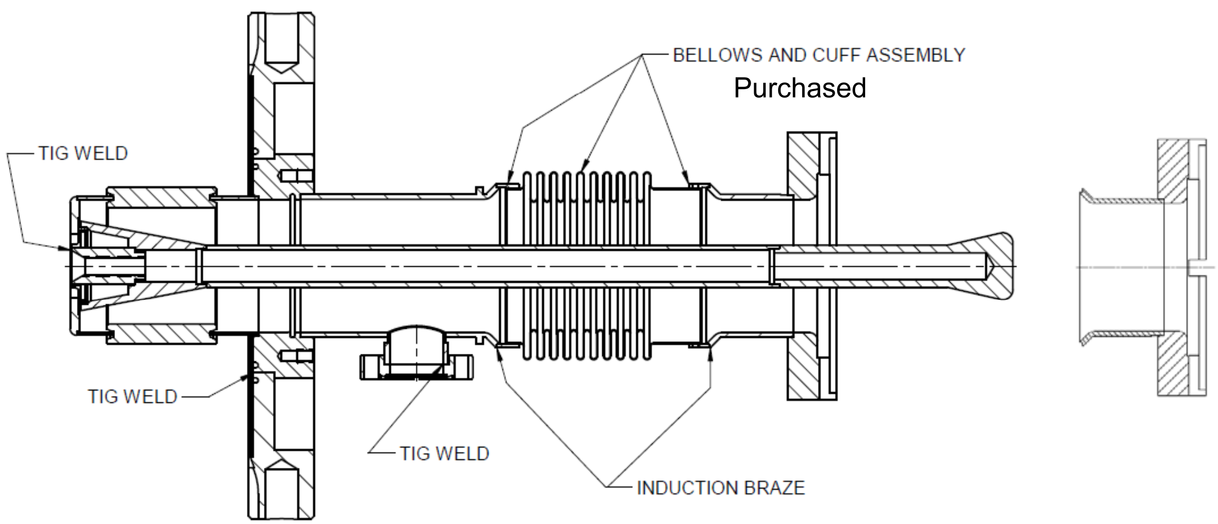


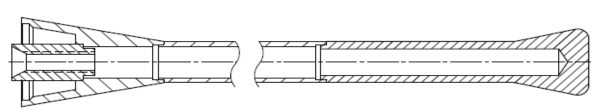
Fabrication Simplification

Currently building a ‘cold’ coupler section using TIG welding and induction brazing of parts assembled using conventional brazing techniques (Cu plate parts first, then braze and TiN coat window before final assembly). The antenna is hollow and vents to the warm section.



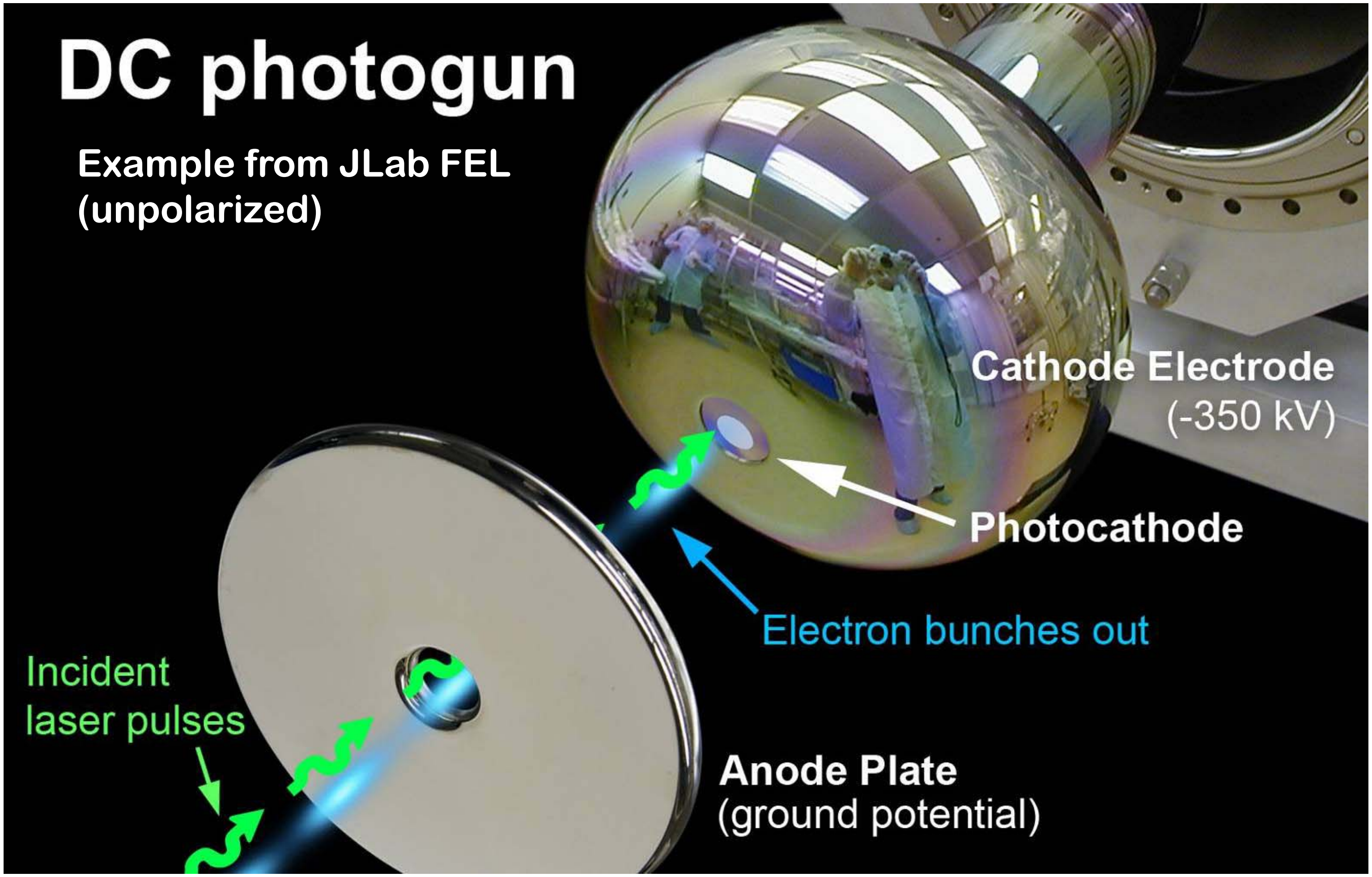
Conventional brazements and final assembly





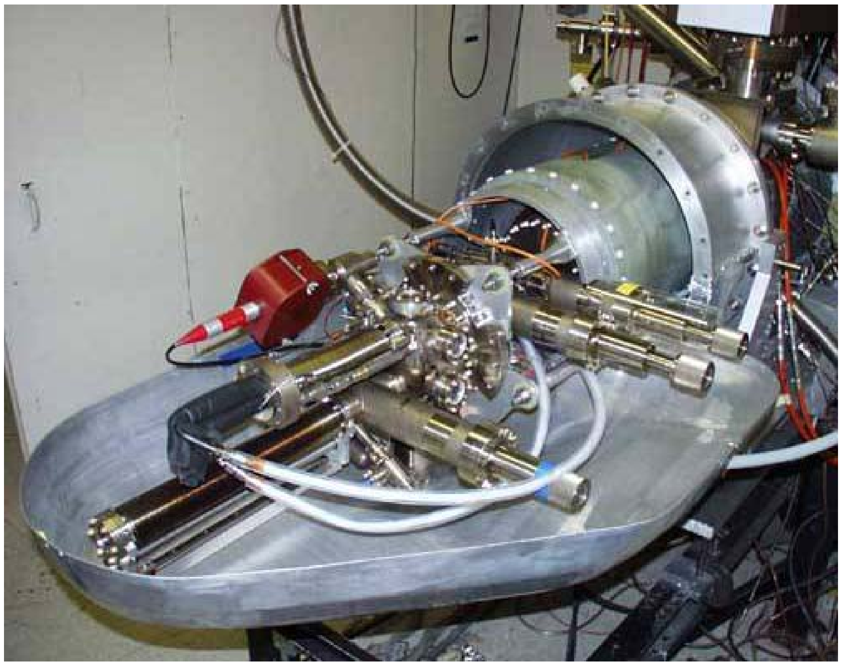
Electron Source R&D

Bunches are generated when the GaAs photocathode is illuminated by pulses of light from a drive laser – for ILC, use circularly polarized light to generate polarized electrons

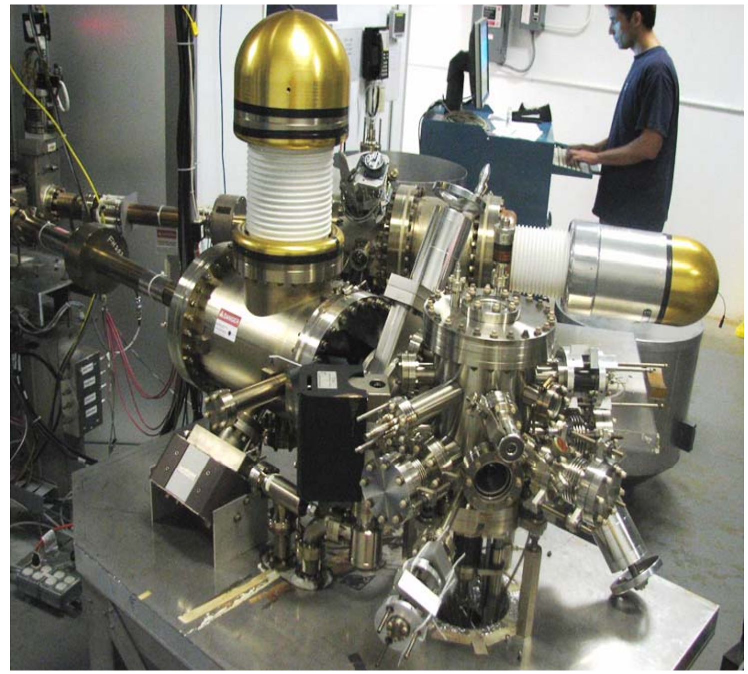


C. Hernandez-Garcia, JLab

SLAC Polarized 120 kV Electron Gun



Jefferson Lab Polarized 100 kV Electron Gun

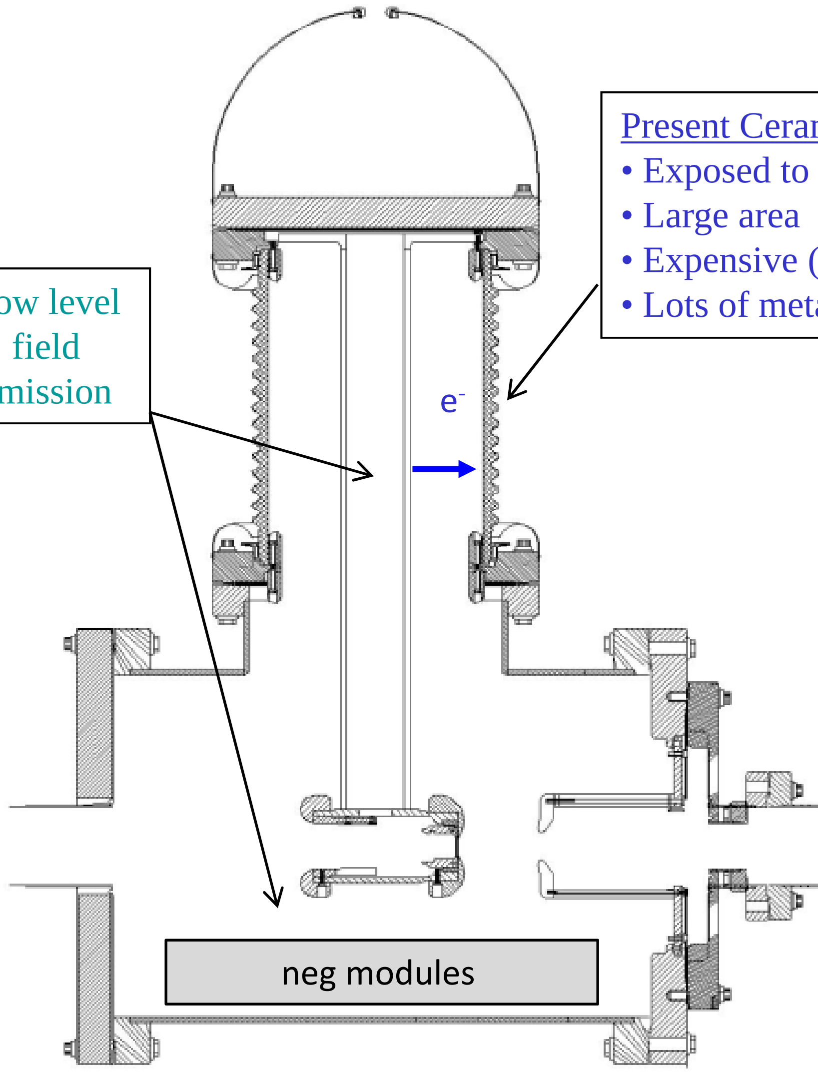


Currently assembling a multi-pass Ti:sapphire amplifier laser system at SLAC to produce 790 nm, 5 uJ pulses at 3 MHz that will generate the an ILC-like bunch train: 2600, 3e10, 1 ns long electron bunches per pulse with > 80% polarization

JLab “Inverted” Gun

In parallel, JLab will try to increase gun HV to 200 kV (2.8 MV/m cathode, 7 MV/m max) using an ‘inverted’ insulator design to reduce space-charge induced emittance growth

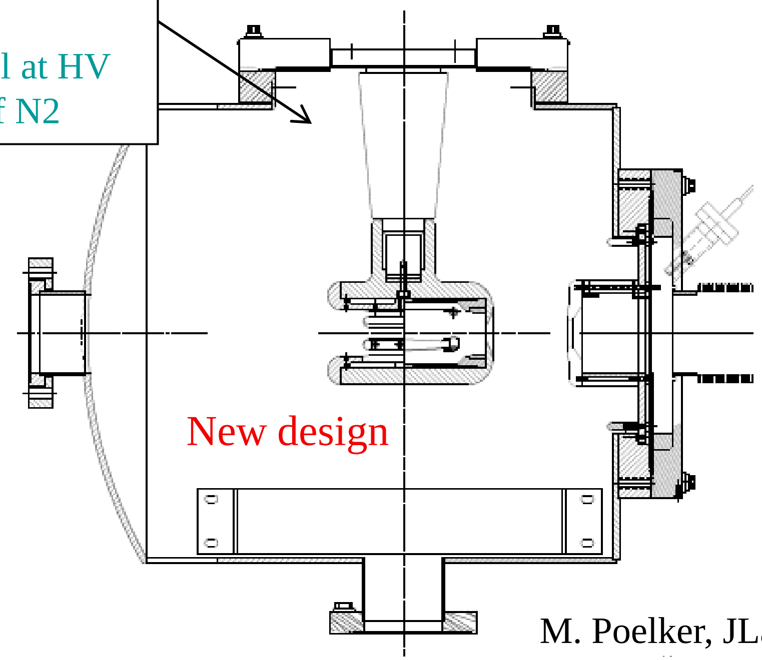
Low level field emission



Present Ceramic
- Exposed to field emission
- Large area
- Expensive (~$50k)
- Lots of metal at HV

Medical x-ray technology

New Ceramic
- Compact
- ~$5k
- Less metal at HV
- No SF6 of N2



M. Poelker, JLab

Polarized Electron Source Timeline

- InvGun2 at 140kV
- InvGun3 Start

FY11

FY12

End ILC
R&D phase

FY13

4/2010 6/2010 11/2010 11/2011 1/2012 5/2012 11/2012

Order
Coherent V-18
Pump laser(s)

By end of FY11:
- InvGun3 at 200kV
- Final Laser Demo
- ILC Beam Demo w/SLC Gun and Photocathodes

Beam Test
Summer 2012

Install ILC Gun and Laser at CEBAF during year-long shutdown

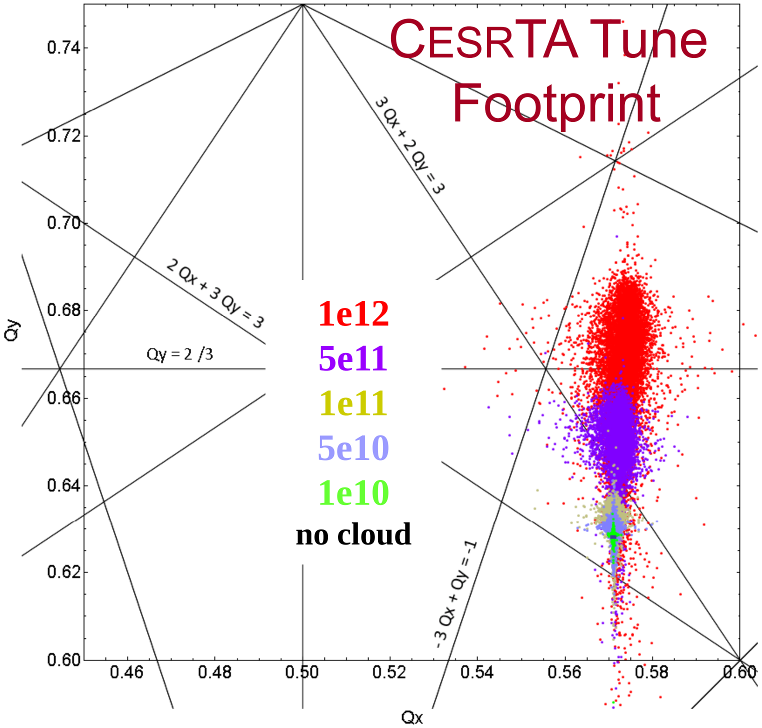
Now:
- Inverted Gun Concept OK at 100kV
- Low Power Laser with ILC Time Structure
- SLC Gun OK at 120kV
- Acceptable Photocathodes

Ship SLAC/ILC Laser to JLab

V-18 Pump Lasers installed Aug 12th at SLAC

SLAC Participation in CesrTA e-Cloud Studies

- Redeployed 3 PEP-II experimental hardware projects in CesrTA, earlier in 2009:
  - SEY *in-situ* measurement system
  - Groove Chambers
  - PEP-II Chicane and Grooved Chamber
- Development of electron cloud models based on CesrTA experimental data and support of simulation effort.
- Participation to CesrTA machine studies



M. Palmer and D. Rubin, Cornell Univ."…We are extremely grateful for the participation of the entire SLAC team. We look forward to continued collaboration with SLAC physicists as we transition from an installation and commissioning phase to low emittance operation of the ring and beam dynamics studies in this regime."

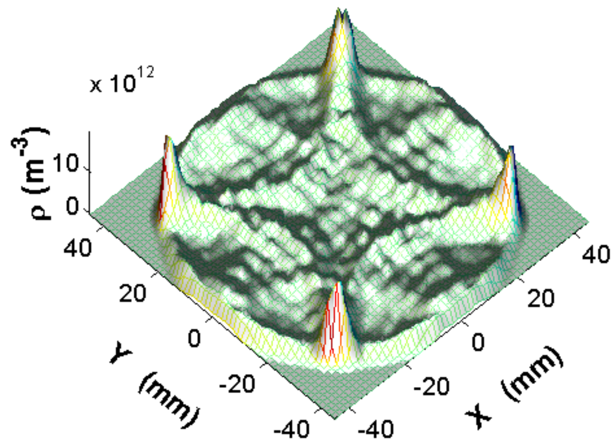
ILC Damping Ring

SLAC is strongly involved in the ILC Damping Ring (DR) system with the:

- Coordination of an international Working Group to address:
  - Recommendation of technical mitigations against the electron cloud formation
  - Reduction of DR size from 6km to 3km
  - Feasibility of shorter bunch spacing from 6ns to 3ns
  - Feasibility of 10Hz DR operation to double luminosity

- Support the electron cloud simulation effort:
  - Development of state-of-the-art simulation codes of e-cloud generation and the resulting beam instabilities
  - Characterization of the electron cloud formation in the rings
  - Characterization of instability thresholds

E-cloud Trapping in a Quadrupole

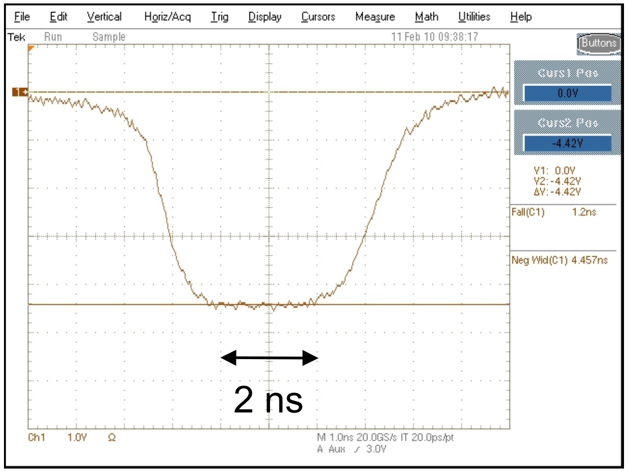


Mitigation in the ILC Damping Rings

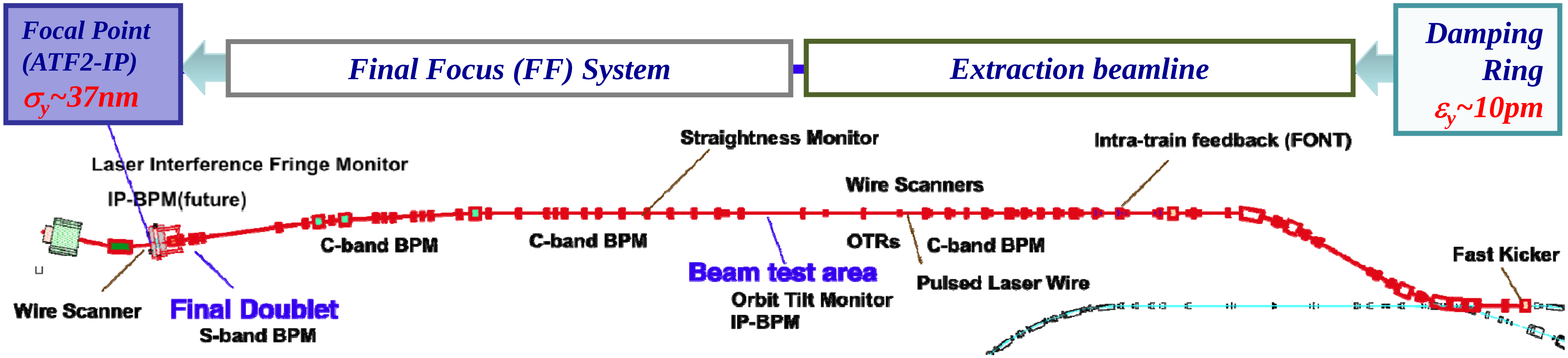
DR element	% ring	Antechamber need	Coating	Mitigation	Additional Mitigation
DRIFT in STRAIGHT	54	No	NEG & Carbon	Solenoid	Grooves
DRIFT in ARC	33	Downstream of BEND only	NEG	Solenoid	Grooves
BEND	7	Yes	TiN	Grooves	
WIGG	3	Yes	TiN	Clearing Electrodes	
QUAD & SEXT	3	Downstream BEND / WIGG	TiN	Grooves	

SLAC DR Kicker Modulator R&D

- SLAC program continues to investigate two approaches to meet the challenging waveform requirements of ILC damping ring kickers: ±5 kV into 50 Ω, 2 ns duration, ~1 ns rise/fall time
- Adder Program
  - Hybrid MOSFET/driver
    - ~1 ns switching time (demonstrated FY08)
    - Improve assembly technique
    - Evaluate thermal stability
  - High bandwidth adder topologies
    - Preservation of pulse fidelity (FY09)
    - Extend to ILC parameters
- Opening Switch Program
  - Uses Drift Step Recovery Diodes (DSRDs)
  - 2-ns prototype demonstrated (FY08)
  - Developing 4-ns modulator for ATF2

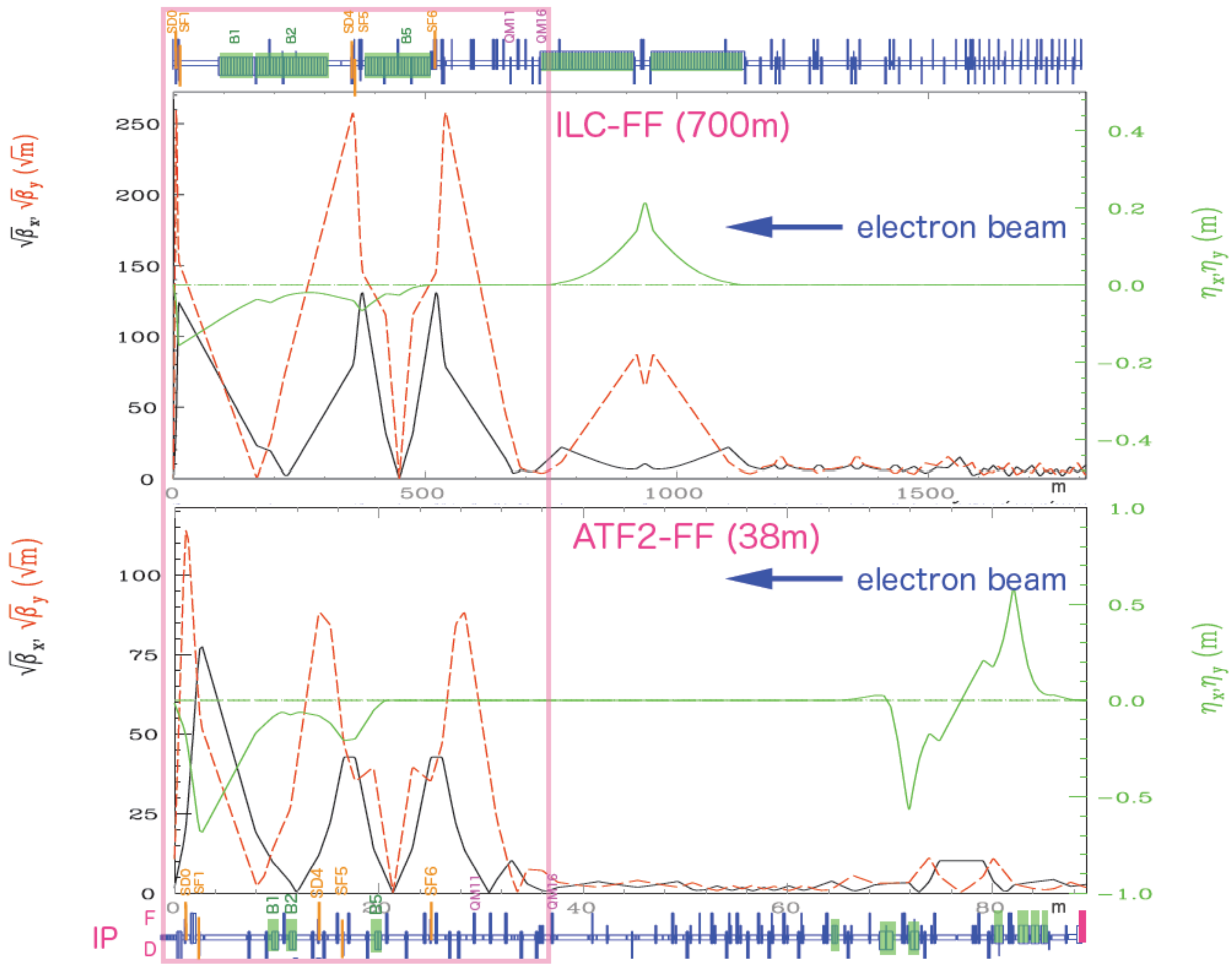


ILC Final Focus Optics and Instrumentation Test Facility at ATF2, KEK



- Experimental verification of the ILC FFS scheme
  - Development of beam tuning and modeling codes
  - Goal A: focus vertical spot at IP to 37nm (single bunch)
  - Goal B: maintain IP vertical position with few-nm precision (multi-bunch)
- Development of ILC instrumentation
  - High resolution BPMs, magnet movers, Fast feedback, Laserwire, beam size monitor, high-availability power supplies, fast pulser, super conducting final doublet…
- Education of young generation for future linear colliders
  - Active participation of graduate students and post-docs.

Scaled Test of ILC Final Focus Optics



- Scaled design of ILC local-chromaticity correction style optics.
- Same chromaticity as ILC optics.
- At lower beam energy, this corresponds to goal ~37nm IP vertical beam waist (300 nm achieved to date).

<u>Typical DR Parameters</u>
ε_x / ε_y = 1.3nm / 8-10pm
E = 1.282 GeV

<u>ATF2 IP parameters</u>
β_x / β_y = 4cm / 0.1mm
σ_x / σ_y = 6um / 37nm
Rep. Rate = 1.56 Hz

SLAC Contributions to ATF2

- Hardware
  - Final doublet quads, FFS sextupoles
  - High-availability Power Supply system for FFS magnets
    - Currently upgrading matching quad system to give bi-polar functionality
  - Magnet mover system for FFS magnets
    - System used at FFTB, new controls s/w for ATF2
  - EXT & FFS C-band cavity BPM electronics
  - IPBPM cavity BPM electronics
    - Currently investigating modifying existing SLAC C-band electronics with improved digitizer system.
  - Multiple OTR system (5 OTRs) for fast emittance and coupling measurements and correction in EXT
  - New EXT stripline BPM readout system, using analogue readout system taken from LCLS design with modified digital readout.
  - Carbon wire scanner system for downstream IP location
    - Now also modifying IP installation to include additional Carbon wire system
- Controls software
  - Built and maintain EPICS controls for SLAC supplied hardware
  - Built and maintain EPICS control environment (save/restore, archive, backup etc)
  - Built and maintain offline simulation layer for EPICS controls
- High level application software
  - Built and maintain portable high-level controls interface system (“ATF2 Flight Simulator”)
  - Built and maintain many high-level machine apps (e.g. IP tuning, orbit feedbacks, dispersion and coupling correction…)
- Simulation
  - Design and testing of FFS tuning knobs
  - Analysis of tuning performance, comparison with ILC etc..

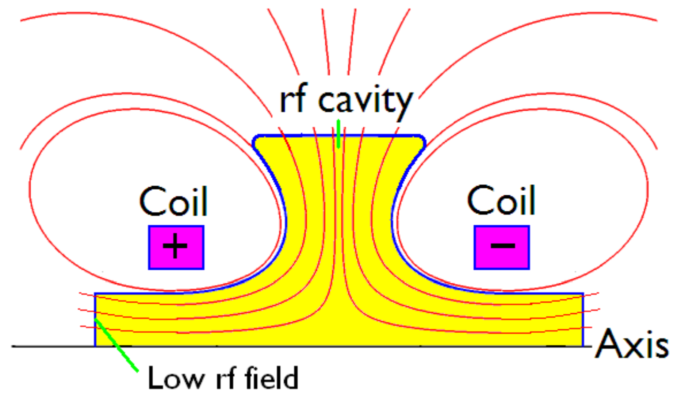
FNAL Project X

- Build on our experience with ILC rf sources to provide wall-plug to coupler rf systems for the 1.3 GHz portions of the CW and pulsed SC proton linacs being considered
- Have scoped 25 kW CW sources: solid state (10 kW unit shown in photo), IOTs and klystrons
- Expect to get ~ 500 k$ in FY11 to do solid state source development
- Also, the SLAC ACD group is currently working with FNAL to evaluate/design a 53 MHz cavity for the Main Injector Upgrade
- Other efforts may include design of the beam chopper and linac beam dynamics studies

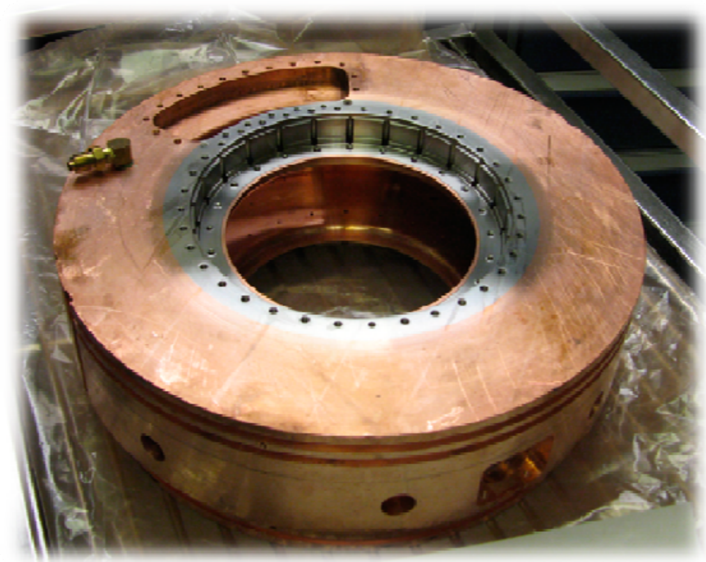
Muon Accelerator R&D

- Exploit extensive experience with breakdown in normal-conducting X-band (11.4 GHz) structures, and recent experience with L-band (1.3 GHz) systems to help in the design of the 201-805 MHz cavities required for muon acceleration. Program could include:
- Simulation of dark current trajectories in strong magnetic fields and the cavity surface heating they induce
- Design a magnetically insulated cavity at S-band (2.856 GHz)
- Build a new 805 MHz pill-box cavity using the techniques that have proved successful at SLAC (the FNAL one is nine years old and fairly 'beat-up').

Magnetically Insulated Cavity



FNAL 805 MHz Pill-Box Cavity



Summary

- Contributing to key ILC design and development issues:
  - R&D aimed at cost saving including development of Marx modulator and a surface-based rf source scheme for a single tunnel Main Linac
  - Linac operation with a spread of cavity gradients
  - Polarized electron source demonstration
  - E-cloud mitigation in the Damping Rings
  - Beam delivery studies, ATF2 small spot demonstration and machine detector interface issues
- L-band and X-band experience a good match to future initiatives
  - CW or pulsed SC proton linac
  - Low frequency, high gradient, magnetically-immersed cavities for muon acceleration