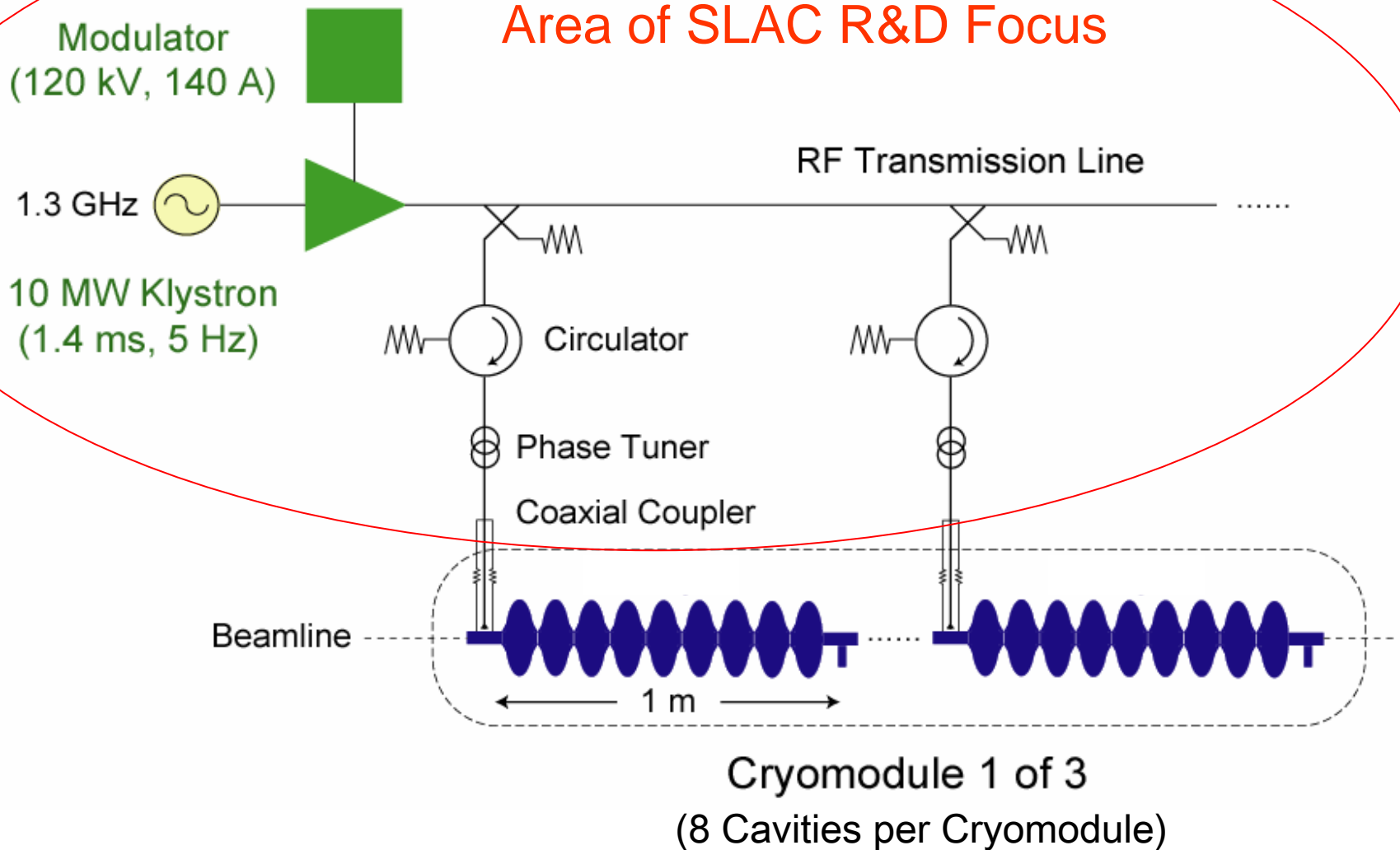




SLAC Update

Chris Adolphsen

ILC Linac RF Unit (1 of ~ 600)

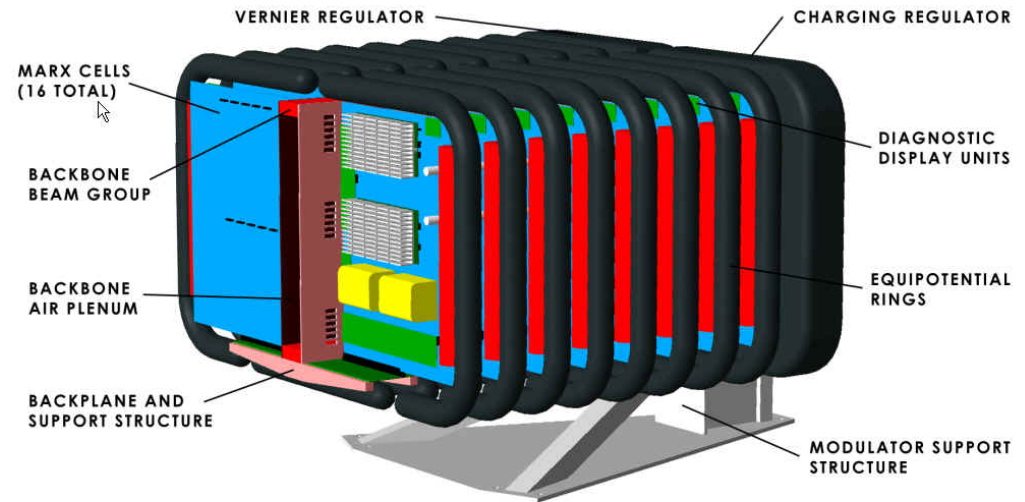


Modulators (120 kV, 130 A, 1.6 ms, 5 Hz)

Baseline: Pulse Transformer
Style Modulator



Alternative: Marx Generator
Modulator



(~ 2 m Long)

Motivation: Reduce cost, size and weight,
improve efficiency and eliminate large oil-
filled transformer from tunnel.

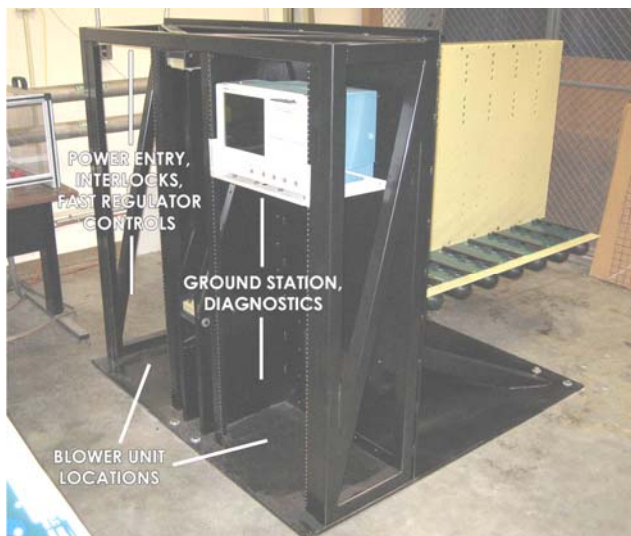
Will test full prototype in 2006

Marx Features

- Direct-coupled voltage stack of ten 12-kV cells producing 140A pk @ 1.6 msec.
- Cell can operate with failed components.
 - 4/5 redundant solid state output, re-charging switch banks.
- Modulator functions with up to 2 failed drivers
 - 10 needed, 12 available
- Vernier cells correct flat top to +/-0.5%.
 - Second stage correction also being studied to approach +/-0.1% if possible.
- Buck regulators (2) have 4/5 switch redundancy

Marx Modulator Status

- Modulator support structure, backbone, complete.
- First 12 kV prototype Marx cell tested at full voltage and current
 - Survives ‘spark-down’ tests to simulate shorted load
- Equipotential rings, connection planes complete.
- PPS system for modulator 30% complete
- Air cooled 150 kW test load 50% complete



Other Alternative Modulators

SNS High Voltage Converter Modulator (Unit installed at SLAC)

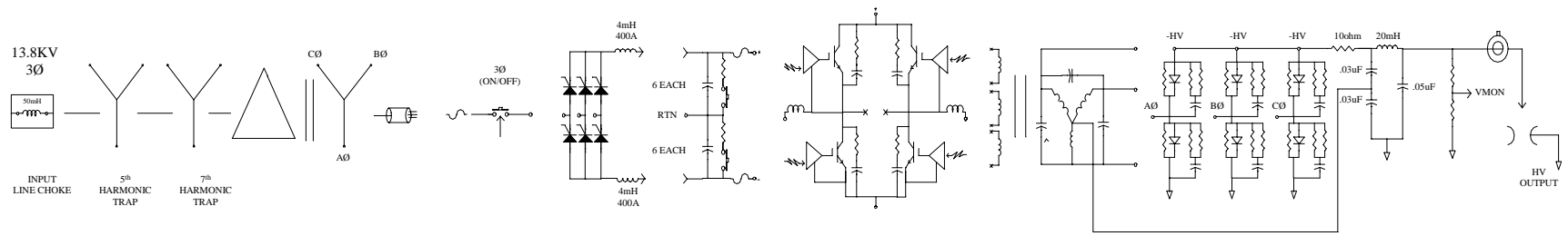
RECTIFIER TRANSFORMER AND FILTERS

SCR REGULATOR

ENERGY STORAGE SWITCHING

BOOST TRANSFORMER

HV RECTIFIER AND FILTER NETWORK



RECTIFIER TRANSFORMER AND FILTERS



SCR REGULATOR



HVCM



EQUIPMENT CONTROL RACK

Series Switch Modulator (Diversified Technologies, Inc.)

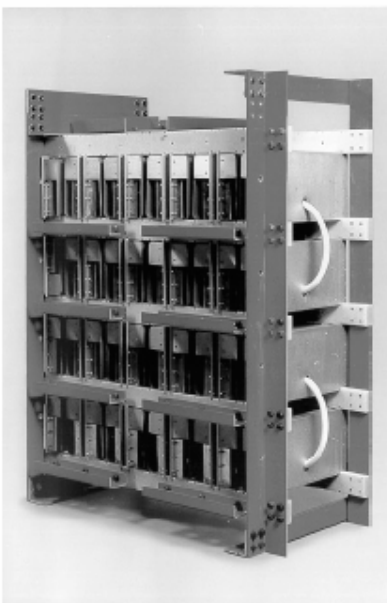
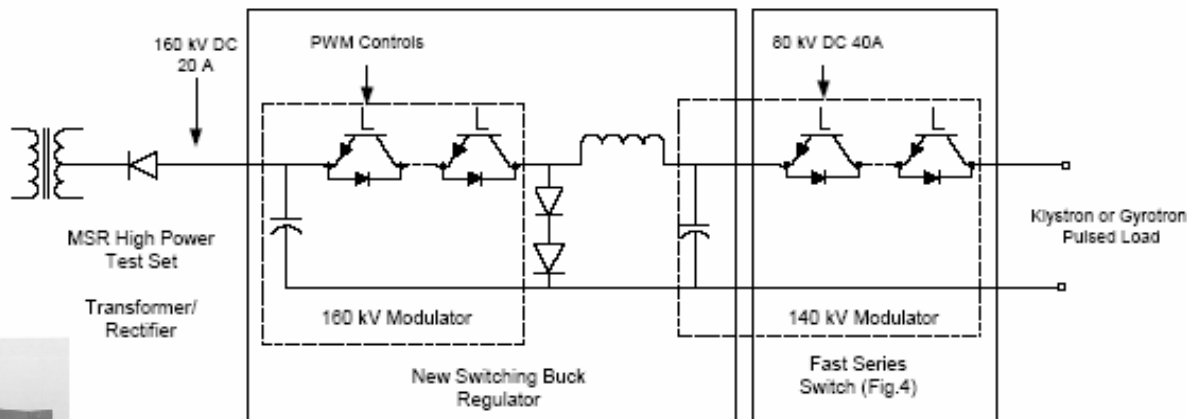


Figure 2. 140kV, 500A solid-state switch

IGBT Series Switch

140kV, 500A switch shown at left in use at CPI

As a Phase II SBIR, DTI is building a 120 kV, 130 A version with a bouncer to be delivered to SLAC at the end of 2006

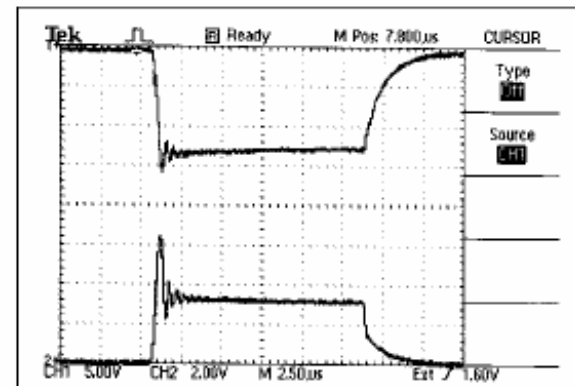


Figure 3: Test pulse (140 kV, 160 A, 13 μsec) of solid-state modulator. Upper trace is voltage at 63 kV/division. Lower trace is current at 100 A/division

FY07 Modulator Program

- Continue evaluation of SNS modulator (recently upgraded in a collaboration with LANL to allow 10 MW klystron operation).
- Establish two new test stands in ESB for DTI and Marx Modulators (start in FY06).
- Install and evaluate first prototype Marx modulator (run > 2000 hours).
- Install and evaluate DTI modulator (run > 2000 hours).
- Develop a Design-for-Manufacture (DFM) Marx Modulator in collaboration with LLNL - order parts for two units to be assembled in house in FY08, but with the circuit board subassemblies and loading let to commercial vendors.

Klystrons

Baseline: 10 MW Multi-Beam Klystrons (MBKs) with ~ 65% Efficiency: Being Developed by Three Tube Companies in Collaboration with DESY



Thales



CPI



Toshiba

Status of the 10 MW MBKs

- Thales: Four tubes produced, gun arcing problem occurred and seemed to be corrected in last two tubes after fixes applied (met spec). However, tubes recently developed other arcing problems above 8 MW. Thales to build two more without changes and two with changes after problem is better diagnosed.
- CPI: One tube built and factory tested to 10 MW at short pulse. At DESY with full pulse testing, it developed vacuum leak after 8.3 MW achieved – has been repaired and will be tested again.
- Toshiba: One tube built, and after vacuum problem fixed, ran at full spec for one day – has been shipped to DESY for further evaluation.
- These are vertically mounted tubes – DESY recently asked for bids on horizontally mounted tubes for XFEL (also needed for ILC).

Alternative Tube Designs

5 MW Inductive Output Tube (IOT)

Peak Output Power	5	MW (min)
Average Output Power	75	kW (min)
Beam Voltage	115	kV (nom)
Beam Current	62	A (nom)
Current per Beam	5.17	A (nom)
Number of Beams	12	---
Frequency	1300	MHz
1dB Bandwidth	4	MHz (min)
Gain	22	dB (min)
Efficiency	70	% (nom)

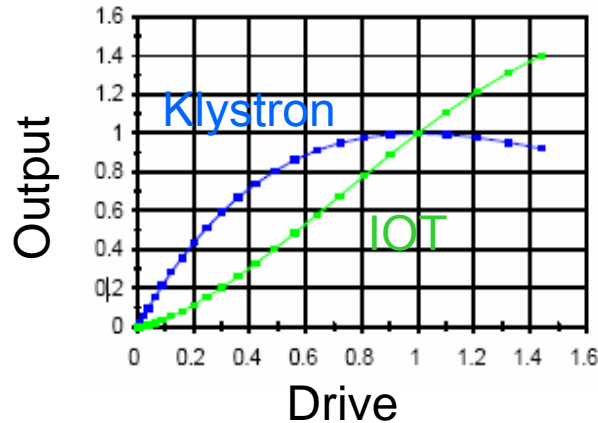
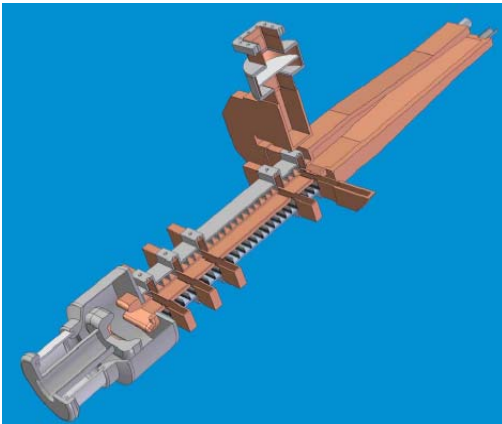
Low Voltage
10 MW MBK

Voltage 65 kV
Current 238A
More beams

Perhaps use a Direct
Switch Modulator

10 MW Sheet Beam Klystron (SBK)

Parameters similar to
10 MW MBK



SLAC

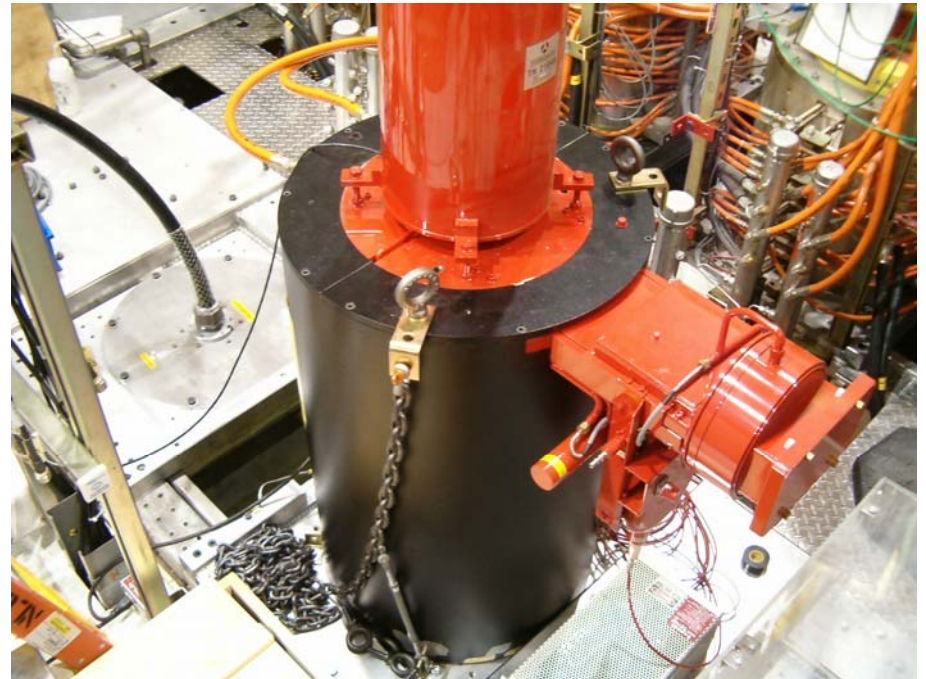
CPI

KEK

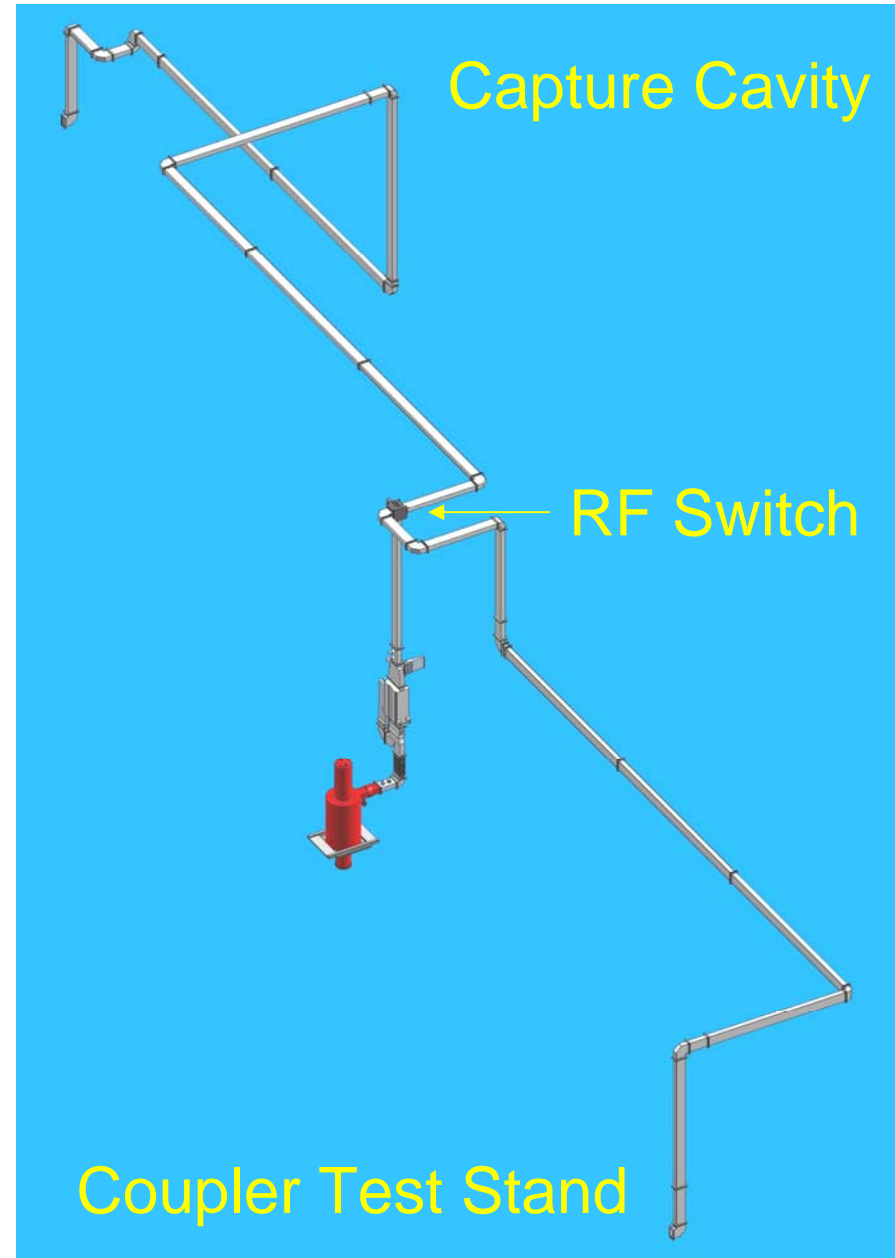
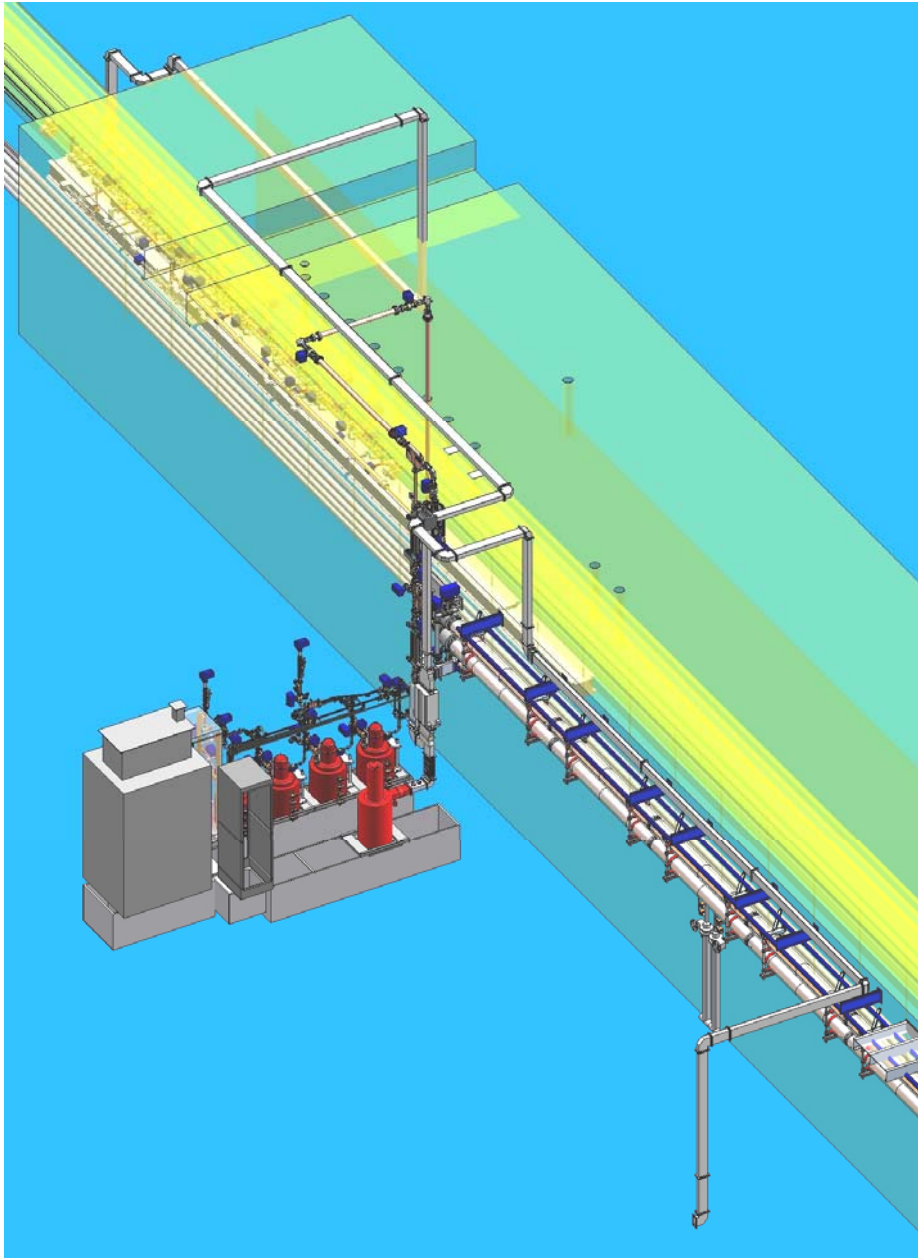
FY06 Klystron Program

- Continue to gain experience with Commercial Thales tubes
 - Have produced 3.3 MW, 1 msec pulses at 5 Hz with a SDI legacy TH2104U klystron powered with the SNS modulator.
 - Expecting delivery of a 5 MW TH2104C klystron (DESY testing workhorse) this month.
 - Use these tubes to power a coupler test stand and a prototype normal-conducting ILC positron capture cavity.

TH2104U Klystron
(red) with Solenoid
(black) Installed in an
Oil Tank at ESB

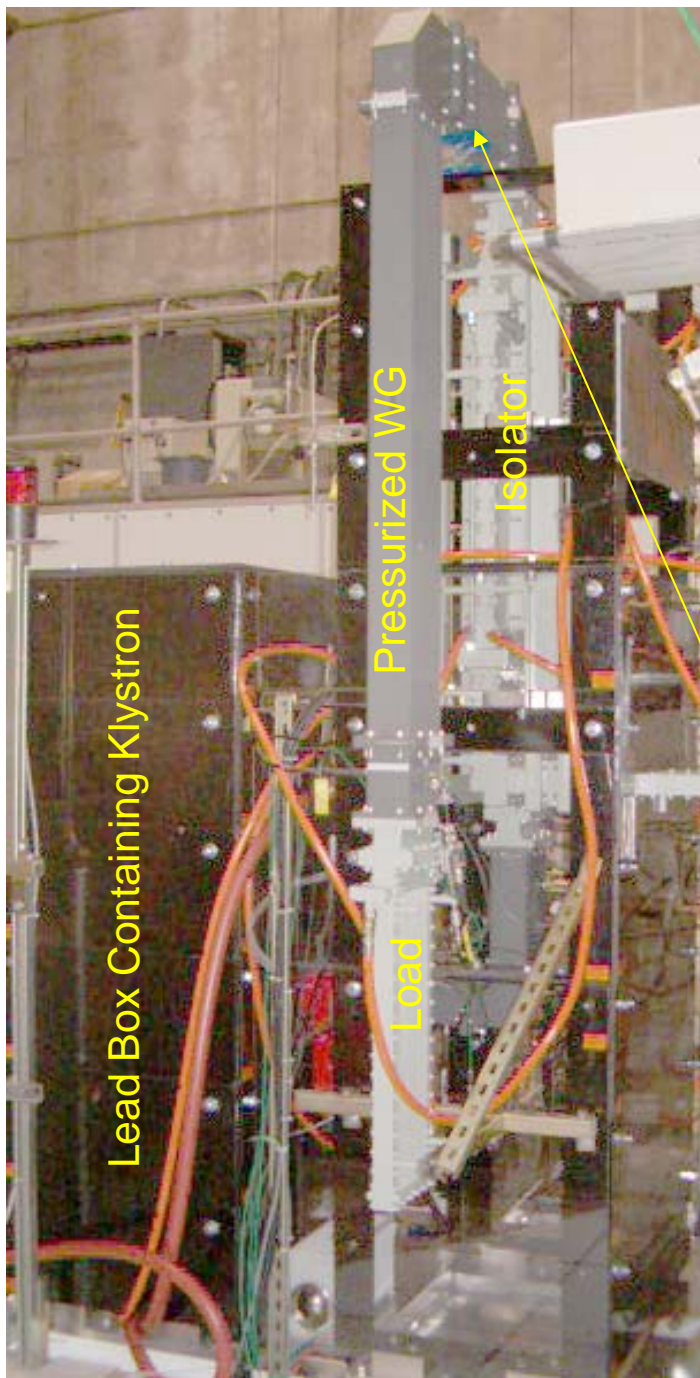


Waveguide Distribution



Waveguide Test Setup

Observed some arcing at waveguide flanges when running with 3 bar N₂ – have since improved the flange flatness and reduced volume of rubber seals to reduce flange gaps



FY07 Klystron Program

- Three-prong approach to producing a robust ILC tube
 - Order second-generation 10 MW klystrons from CPI and Toshiba.
 - Most believe these tubes will work and have long cathode lifetimes (~ 100 khours). However, this forces a larger, more complex design,
 - Develop a 10 MW sheet-beam klystron at SLAC
 - Considered most risky approach but has the largest potential for cost savings.
 - Contract industry to build a higher efficiency, 5 MW, single-beam tube
 - Commercial 5 MW tubes are reliable, but have low efficiency (42%).
 - Considered a conservative approach, however, will likely require higher voltage modulator, which may decrease reliability of both the tube and modulator.
 - CPI and L3 Communications expressed interest in developing this tube.

Sheet Beam Klystron Motivation

Plug-compatible ILC RF Source replacement

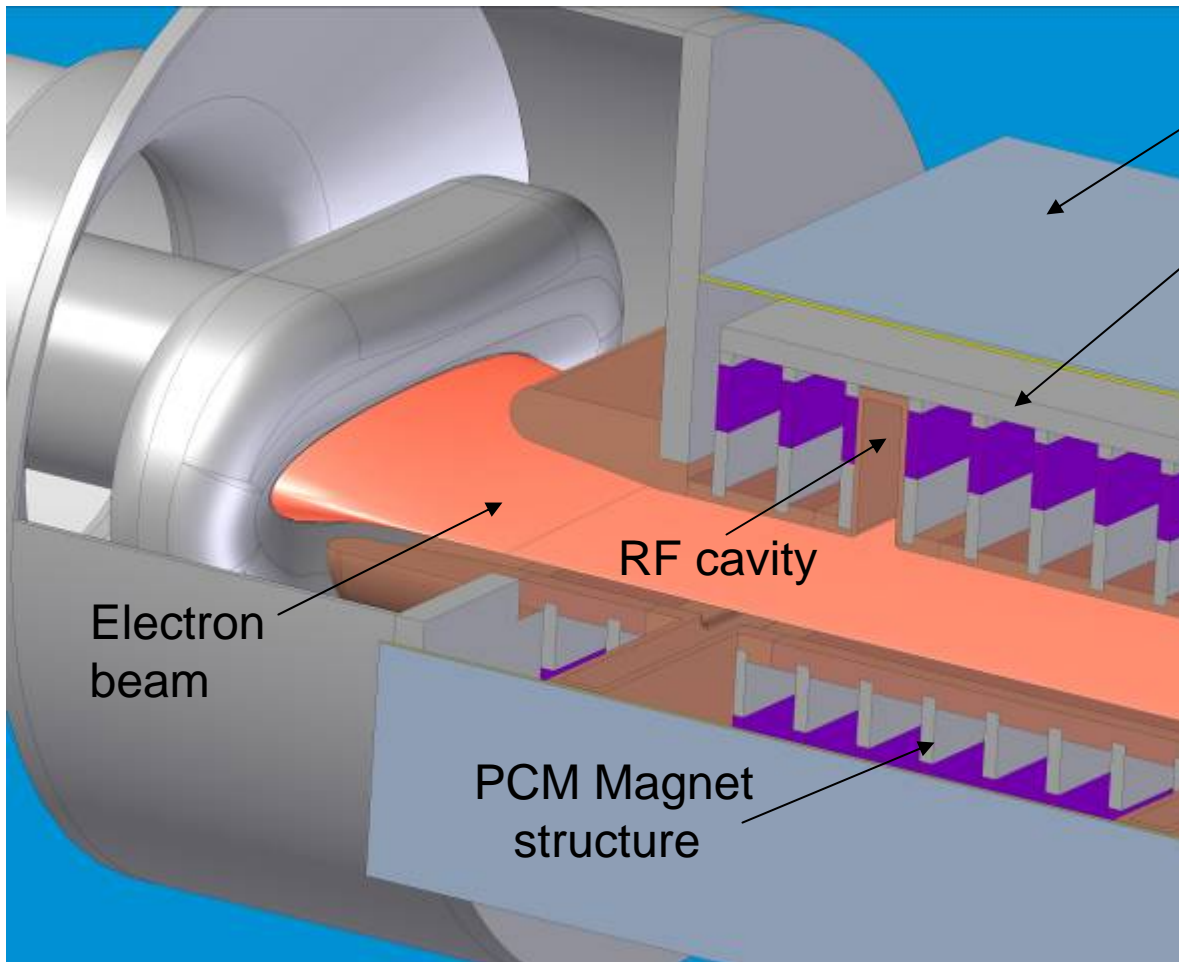
Large internal surface areas – low cathode current and power densities, low temperatures → ***very robust***

No solenoid power required - lighter, and simpler than MBK devices → ***lower costs***

Fewer parts than MBK devices – higher yields → ***lower costs***

Beam Transport and RF

130 A elliptical beam enters a PCM magnet stack with cavities inserted between magnets



Lead shielding

Magnetically shielded from outside world

3D Gun simulations give 130 A 40:1 aspect ratio elliptical beam

3D magnet simulations of 30 period structure

3D PIC Code for RF

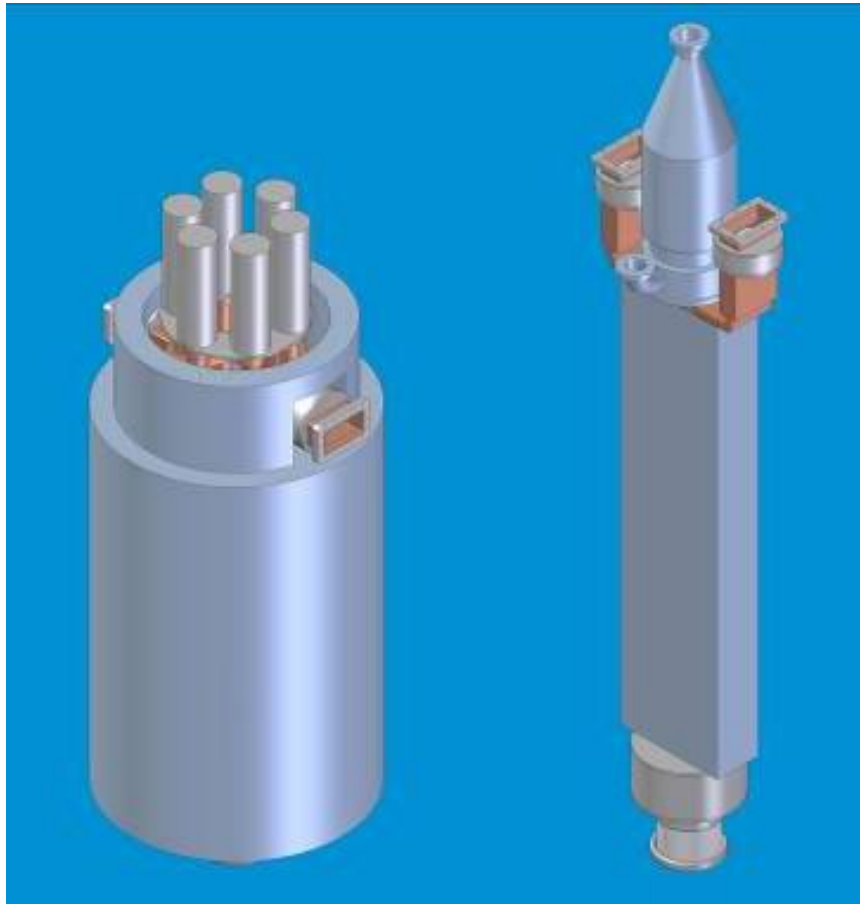
Size and Beam Focusing

ILC MBK vs. SBK

MBK's:

~5000 lbs.
91" - 98" long
35" - 45" wide

Solenoid power
4-8 kW



SLAC SBK:

921 lbs.
122" long
28" wide

No solenoid
power required!

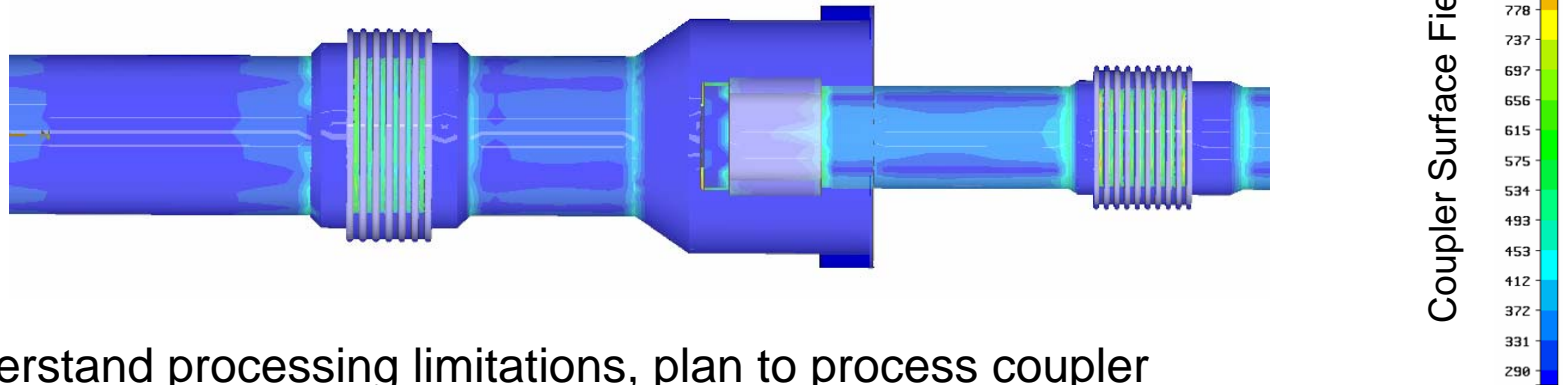
Sheet Beam Schedule

(FY06 Work Funded by SLAC)

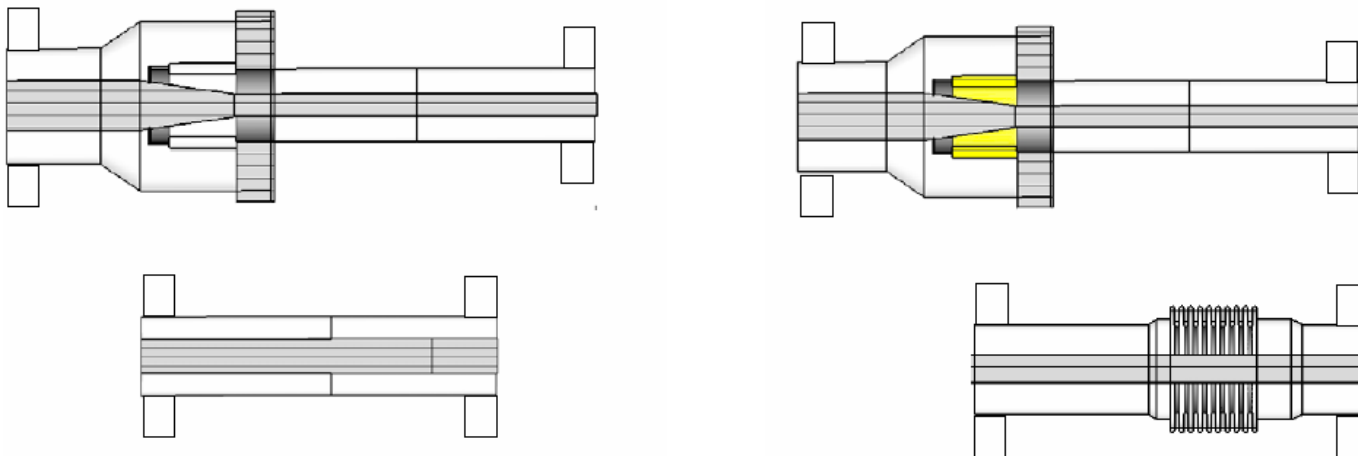
Jun '06	Complete rf beam transport design
Jul '06	Complete gun electrode design
Aug '06	Complete electrical design
Aug '06	Complete mechanical layout
Mar '07	Mechanical drawings
Aug '07	Bake-out of first prototype
Jan '08	Bake-out of second prototype

Coupler Processing Studies

Concern that the surface field variations in the bellows and near the windows may lead to excessive multipacting.

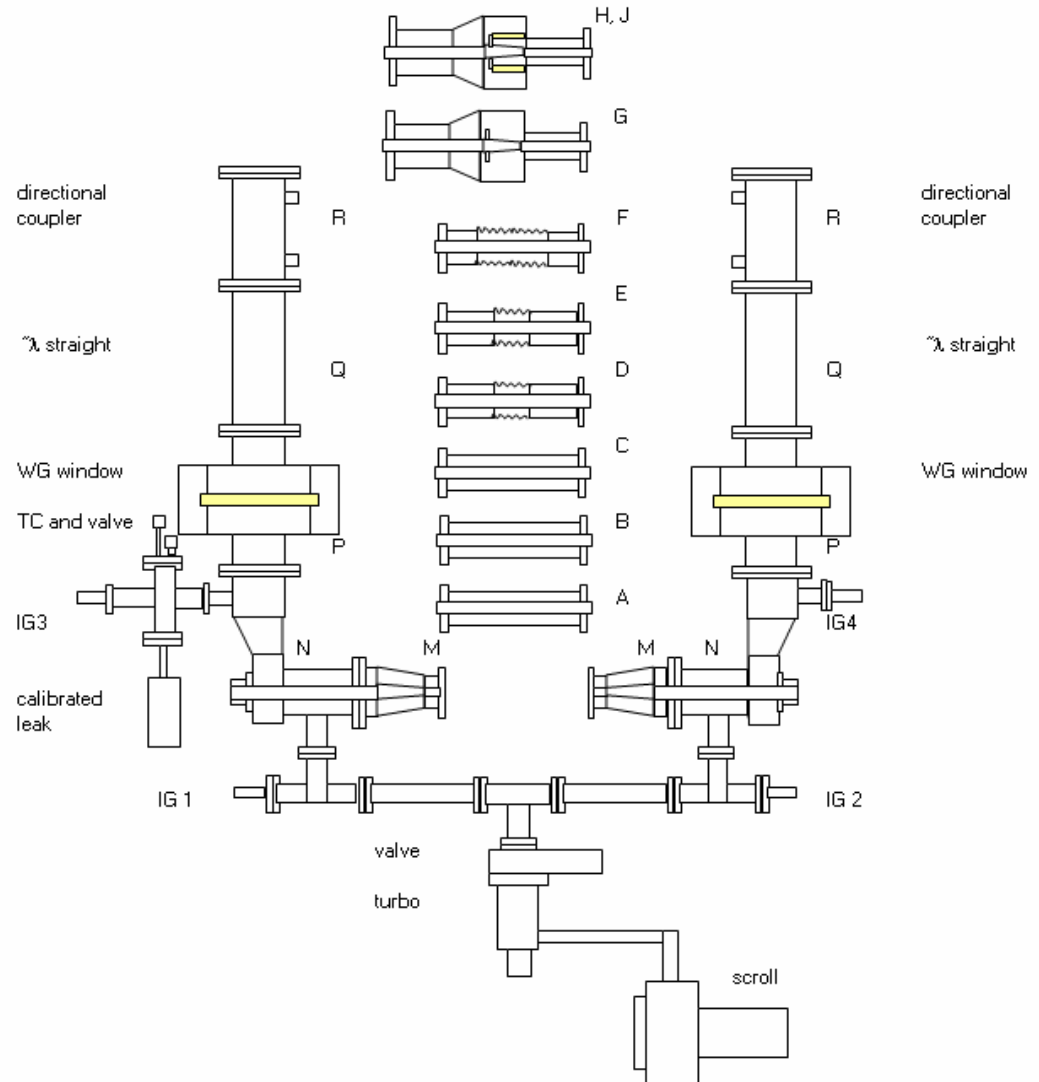


To understand processing limitations, plan to process coupler components individually. In particular, determine if bellows or the windows are the source of the long processing time.

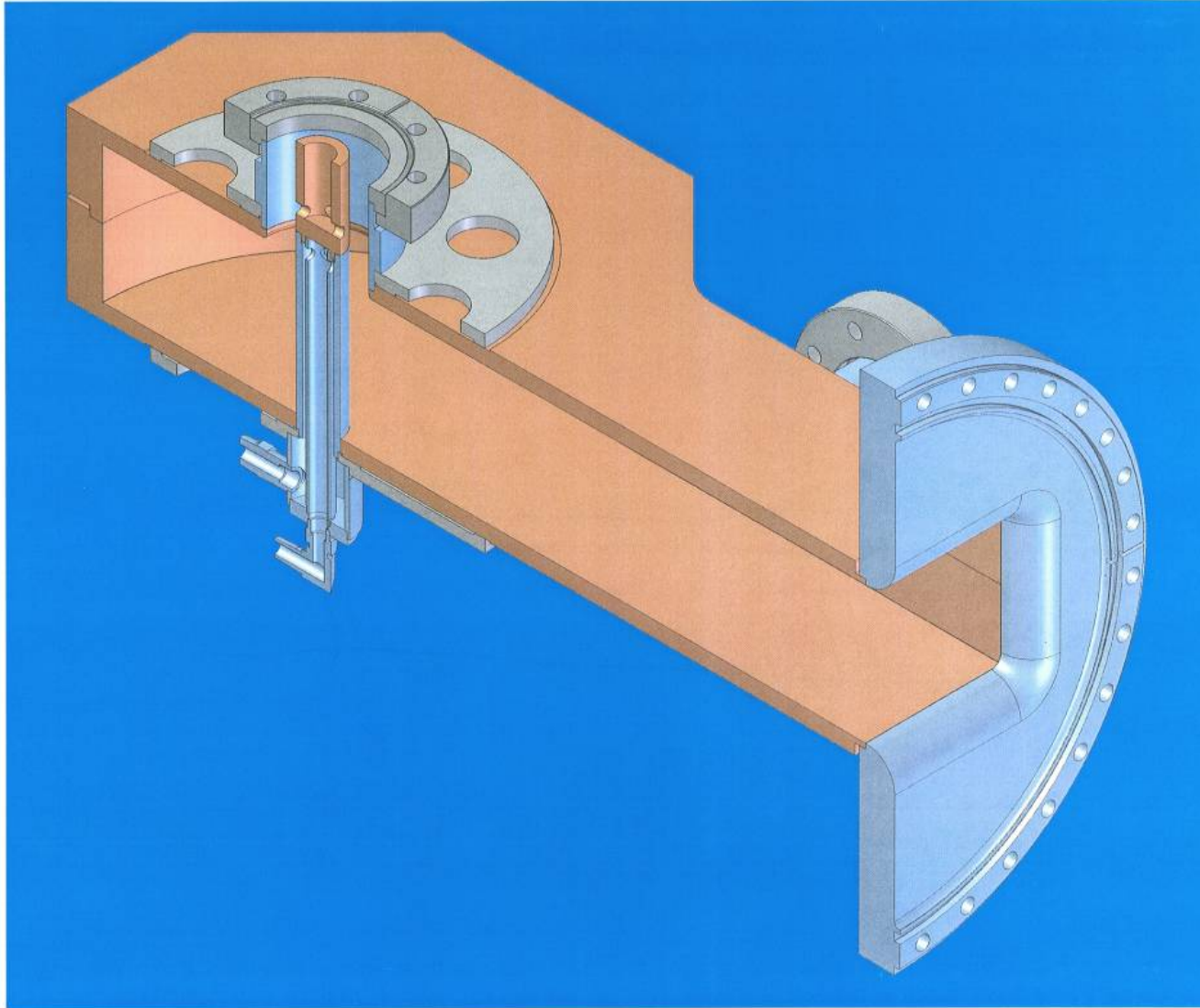


Coupler Development Status

- Have chosen basic layout of system to test coupler parts
- Setup uses a detachable center conductor and 50 cm long test sections
- Currently building waveguide to coax adaptors



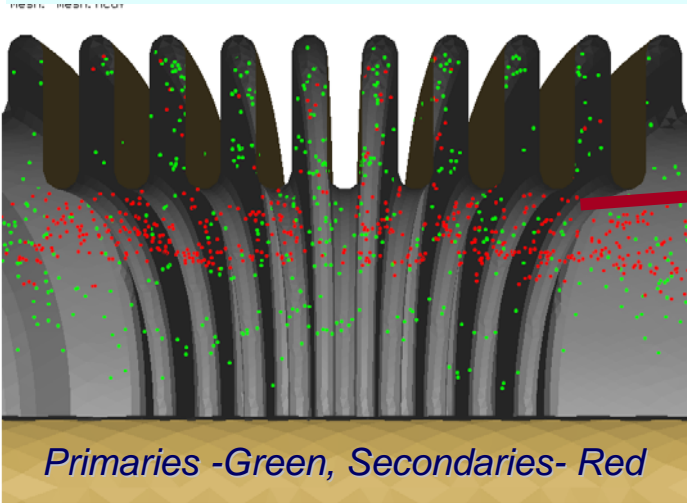
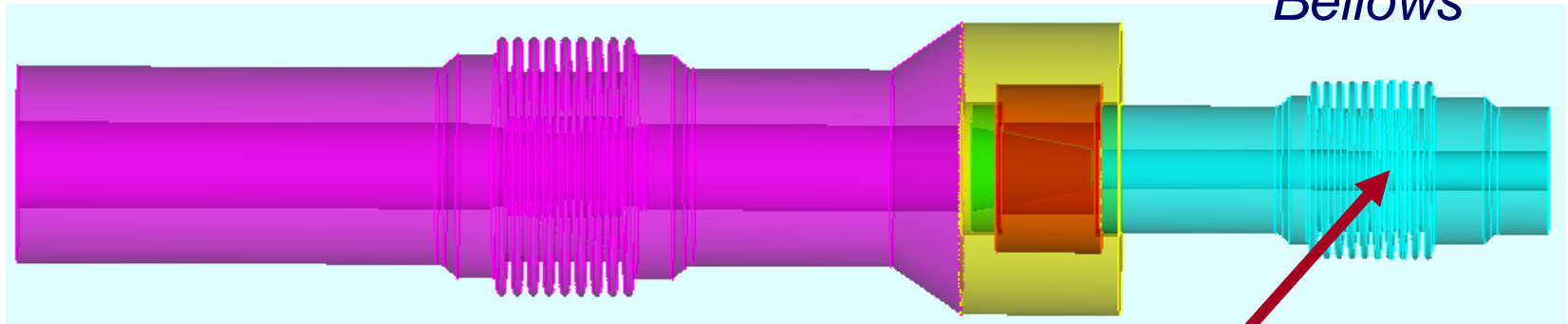
Design of WG-to-Coax Adaptor



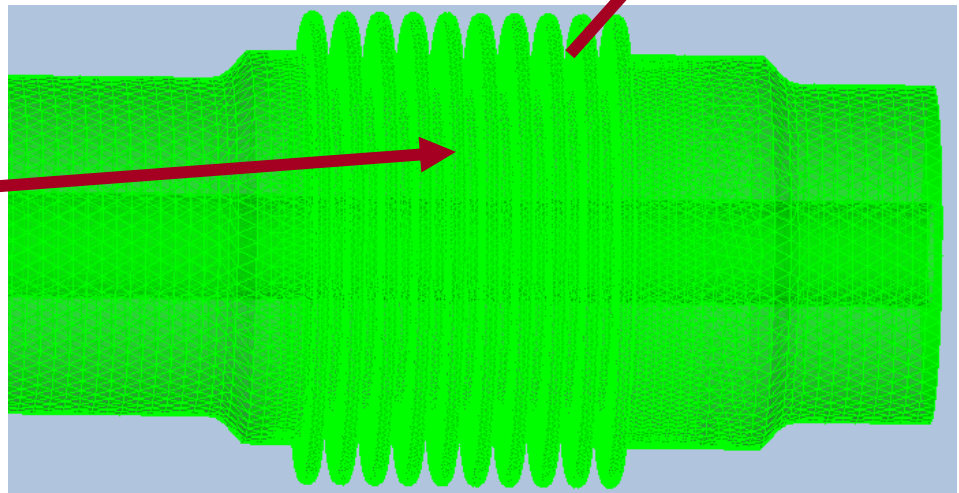
Multipacting Simulation of TTF3 Coupler

“Cold Side”

Bellows



Primaries -Green, Secondaries- Red



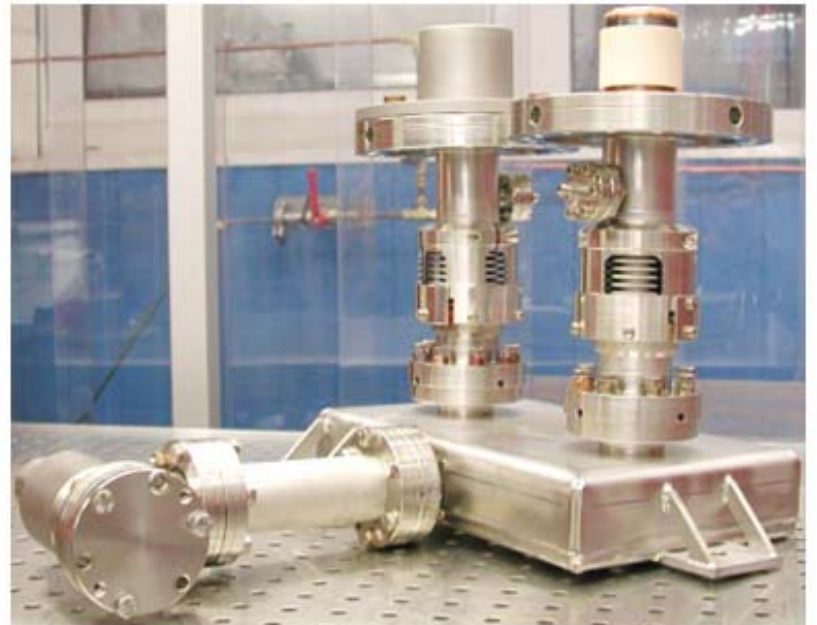
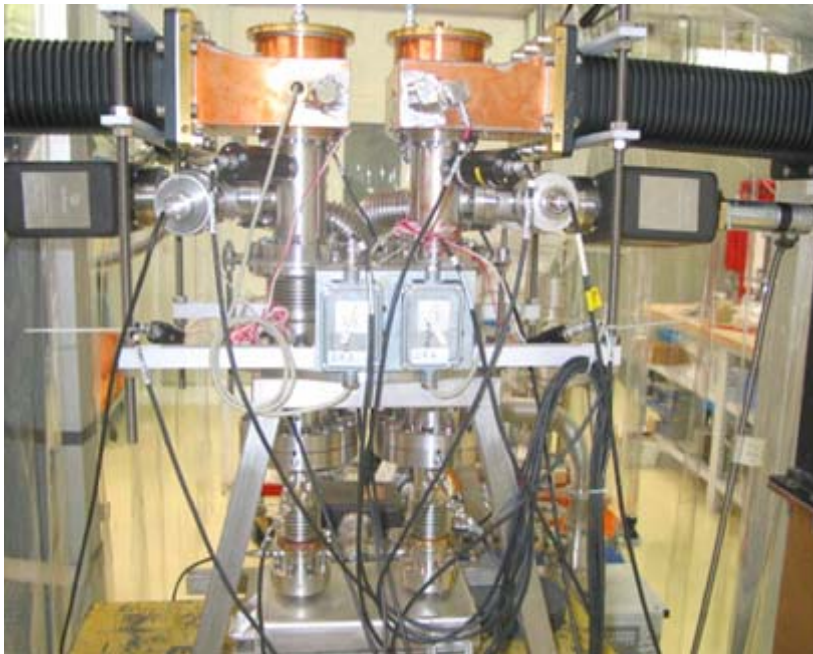
FY07 Coupler Program

(in collaboration with LLNL)

- Build improved version of TTF3 coupler based on
 - Results of FY06 tests of coupler components.
 - Evaluation of design by SLAC klystron engineers to improve reliability and reduce cost (they developed a new L-band window this year).
- Setup facility like that at Orsay to assemble and rf process couplers for the cavities being built for ILCTA
 - Use existing class 1000 clean room and water purification systems at SLAC (buy small class 100 clean room).
 - Use coupler test stand area in ESB to process couplers. EPICS based control system already developed.

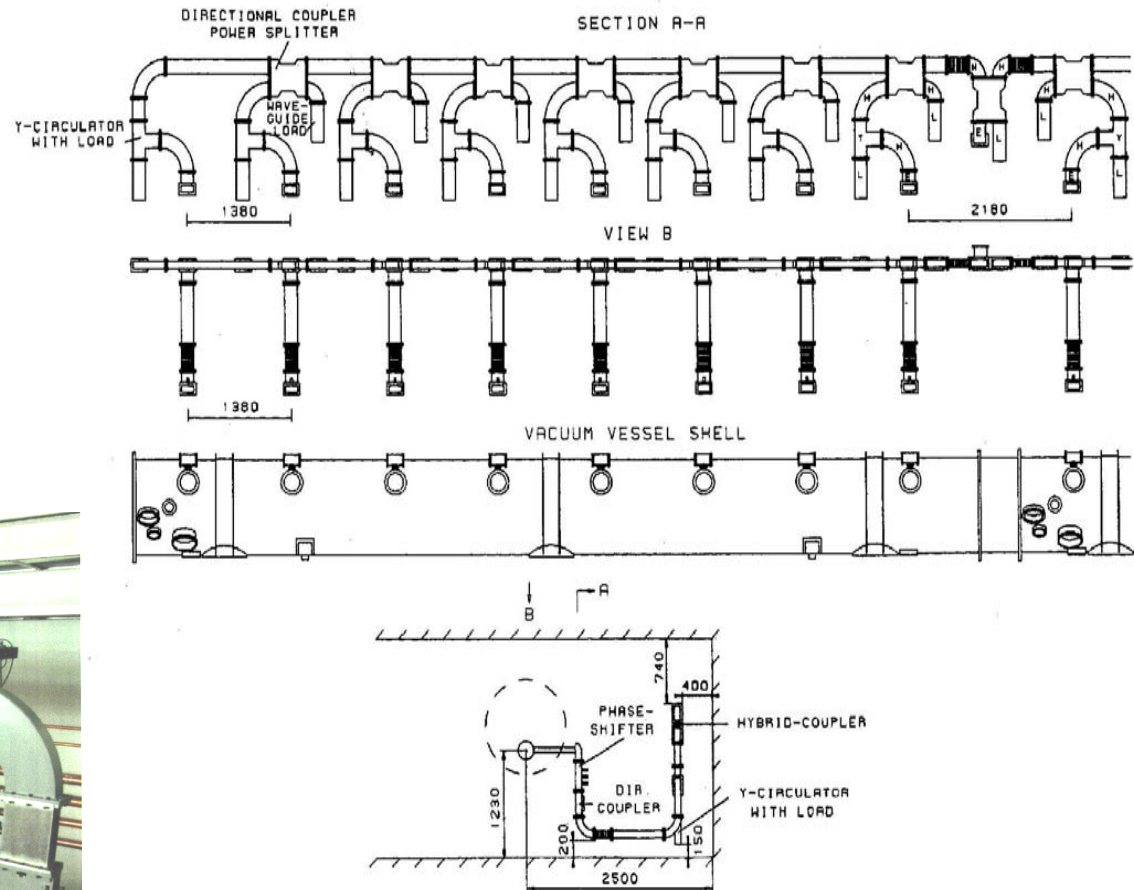
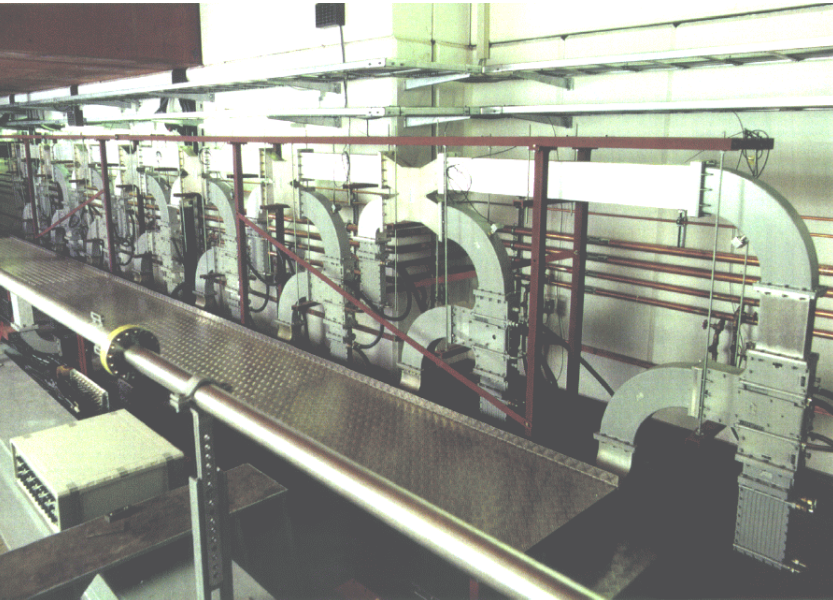
Test Stand to RF Process Couplers

Instrumented Coupler Test Stand at Orsay



RF Distribution

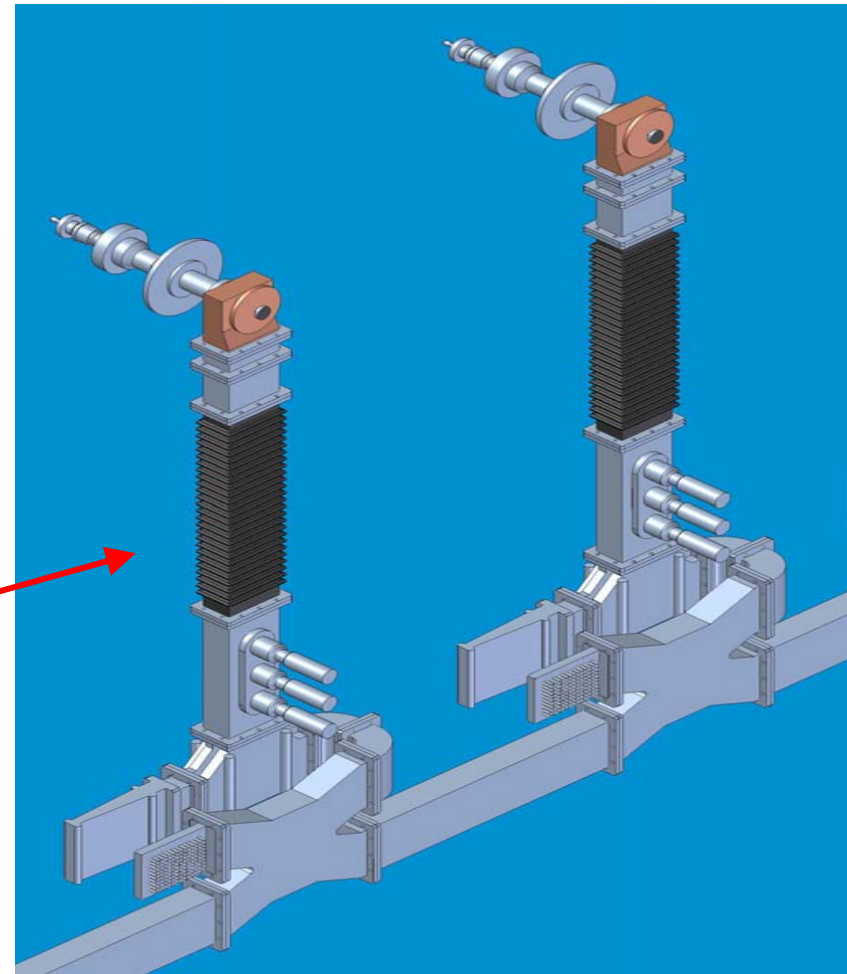
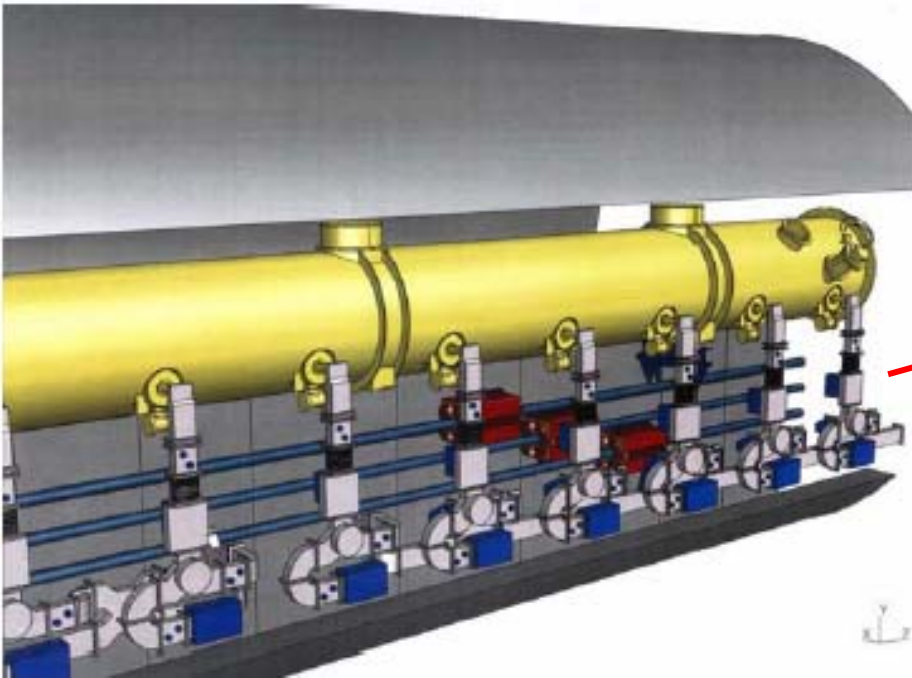
Baseline choice is the waveguide system used at TTF, which includes off-the-shelf couplers, circulators and 3-stub tuners (phase control).



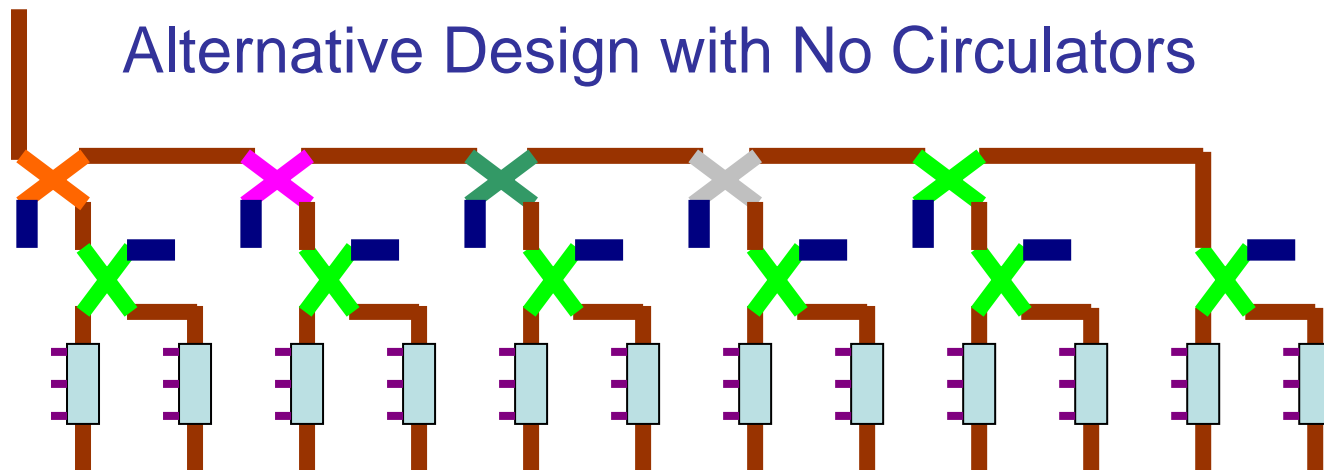
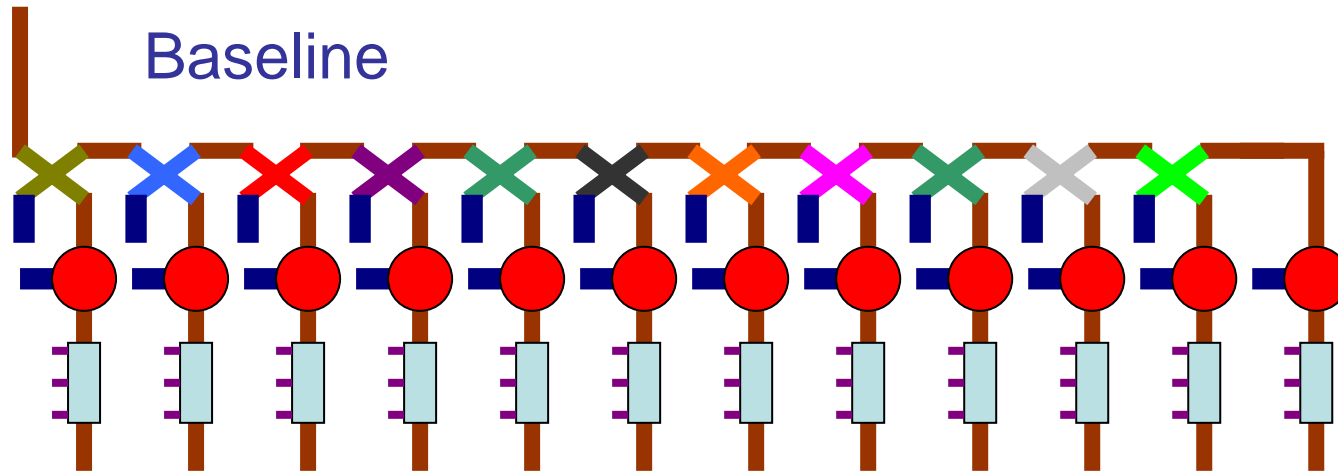
Need more compact design

(Each Cavity Fed 350 kW, 1.5 msec Pulses at 5 Hz)

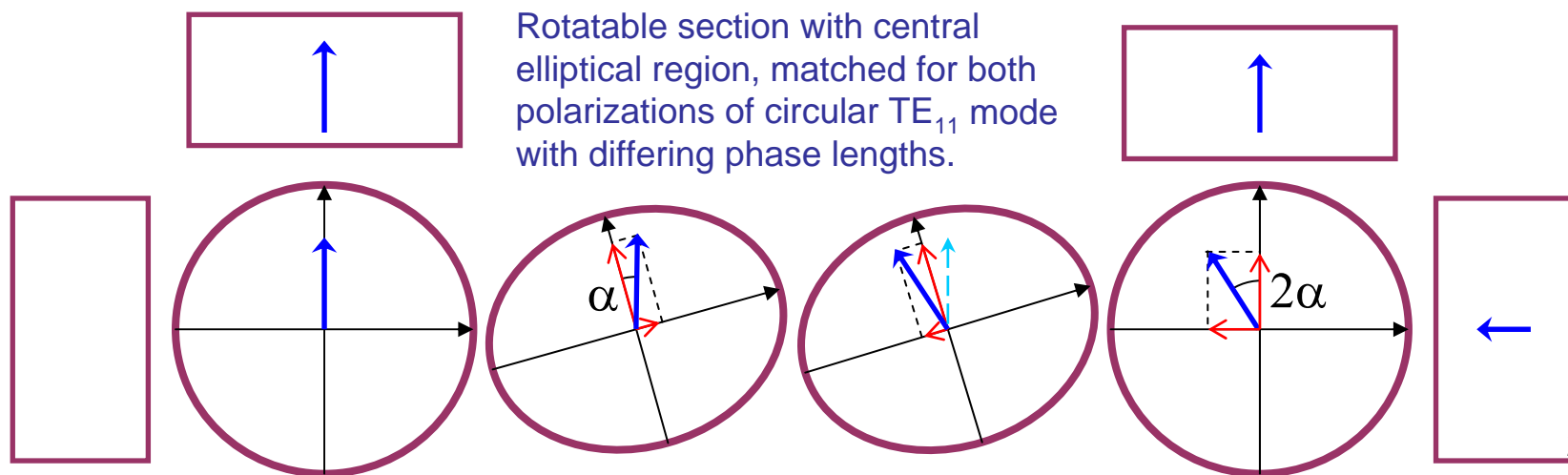
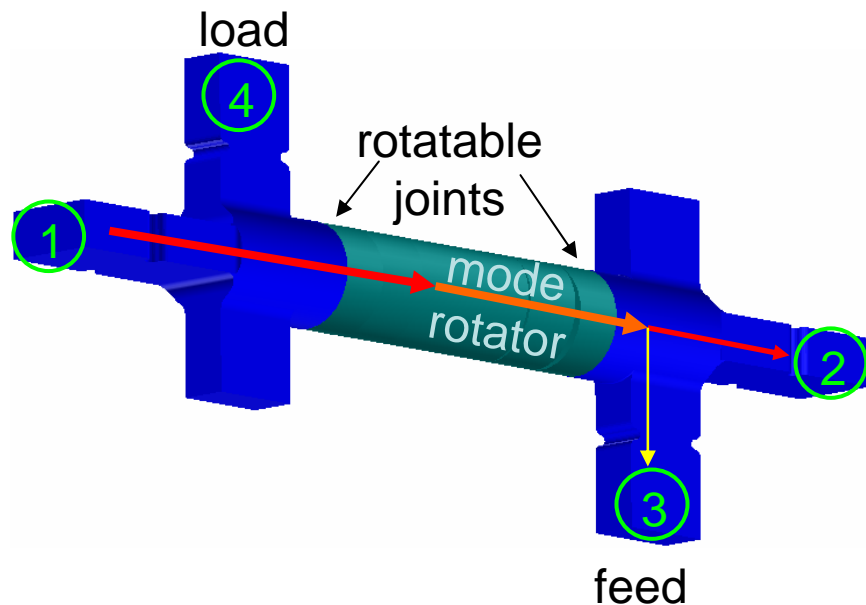
Two of ~ 16,000 Feeds



And should simplify system (circulators are ~ 1/3 of rf distribution cost)

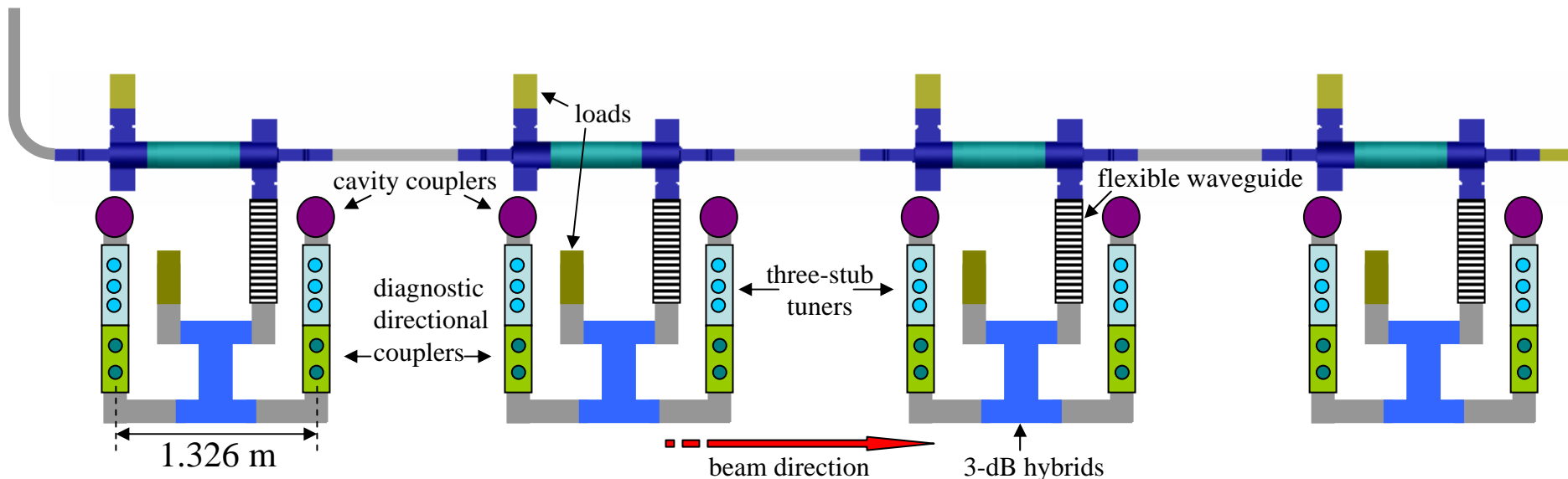


Adjustable Tap-Offs Using Mode Rotation



Proposed RF Distribution Layout

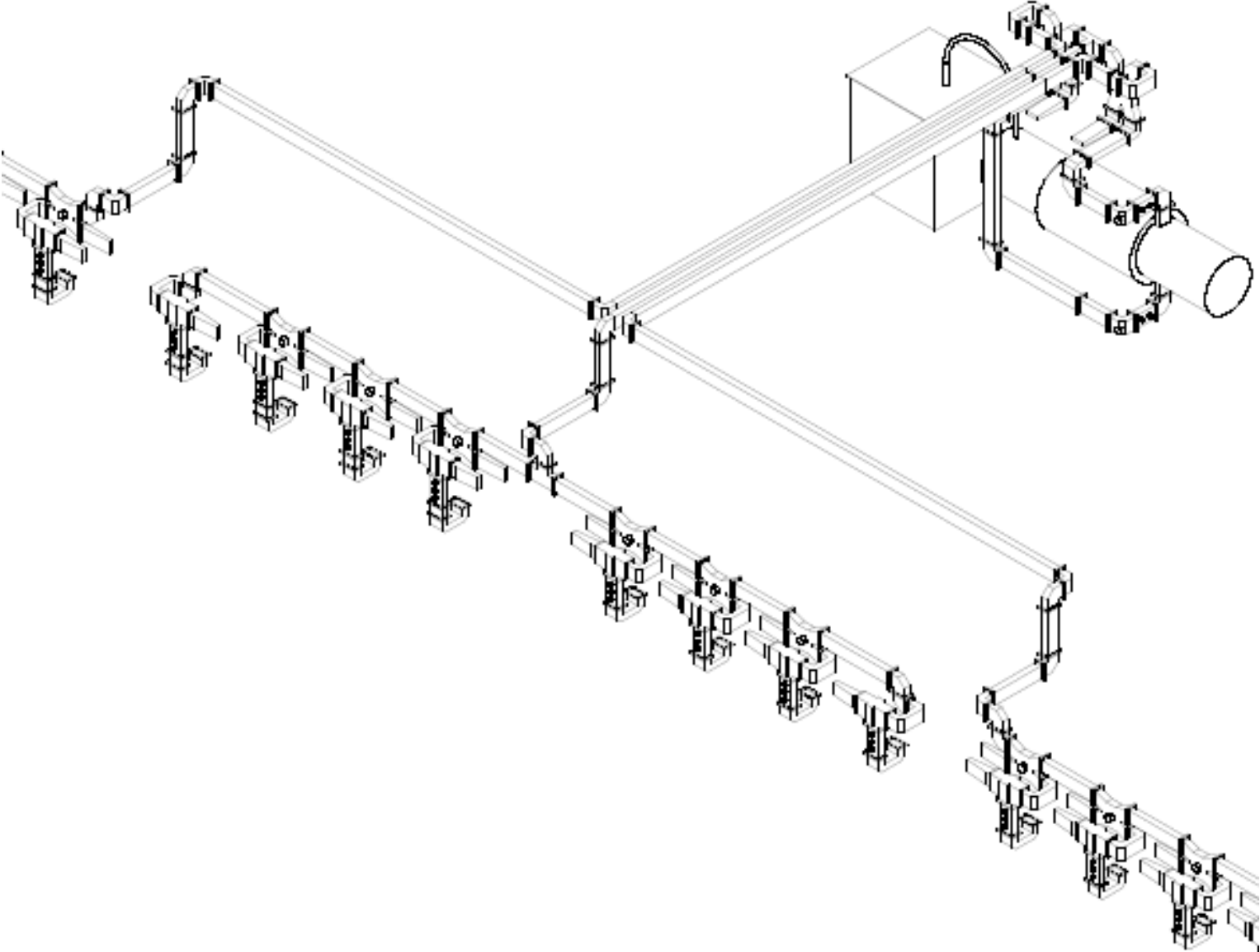
- Adjustable power to pairs of cavities
- No circulators
- Pairs feed by 3 dB hybrids (requires $n\lambda \pm 90$ degree cavity spacing – only 7 mm longer than TDR/BCD spec)



FY07 RF Distribution Program

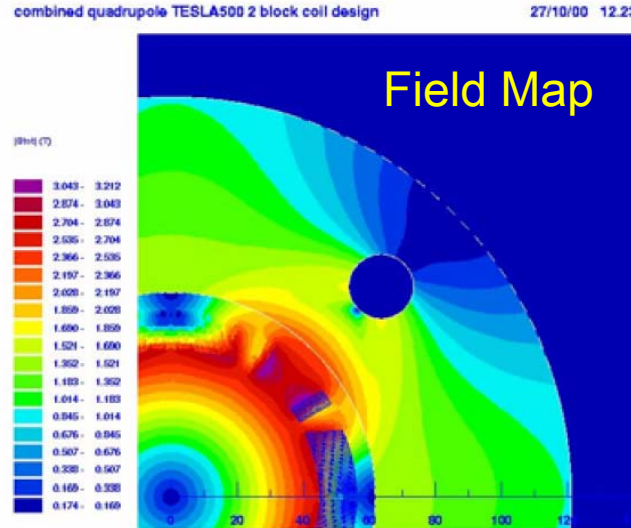
- Test both high and low power circulators.
- Develop adjustable tap-offs and simple phase shifter, and test at high power.
- Build rf distribution systems for the first two FNAL cryomodules ($n\lambda$ cavity spacing).
 - Both would include circulators (needed for beam operation) that could be removed to test cavity-to-cavity rf coupling without them.
 - Second would include a simpler phase shifter in place of 3-stub tuner.
 - The TTF4 cryomodules would hopefully not need circulators.
- Develop methods to weld waveguides together to avoid costly and unreliable flanges.

ILC RF Distribution System

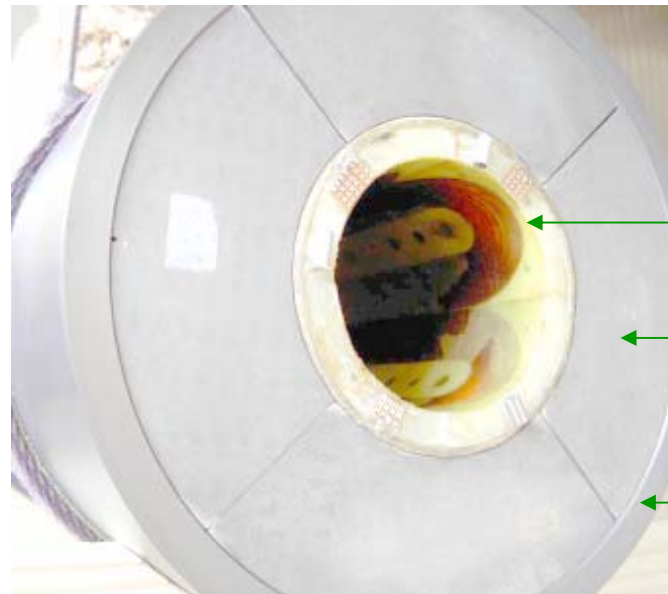
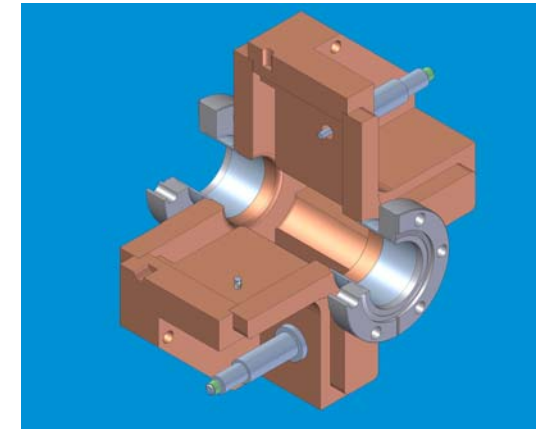


ILC Linac SC Quad/BPM Evaluation

Cos(2Φ) SC Quad
(~ 0.7 m long)



S-Band BPM Design
(36 mm ID, 126 mm OD)

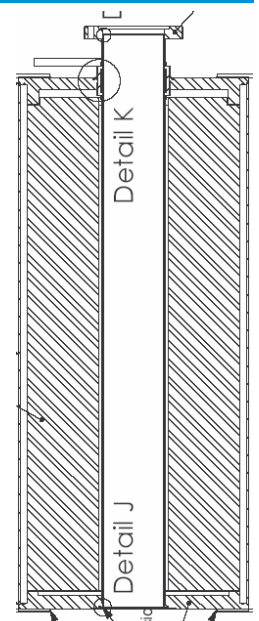


He Vessel →

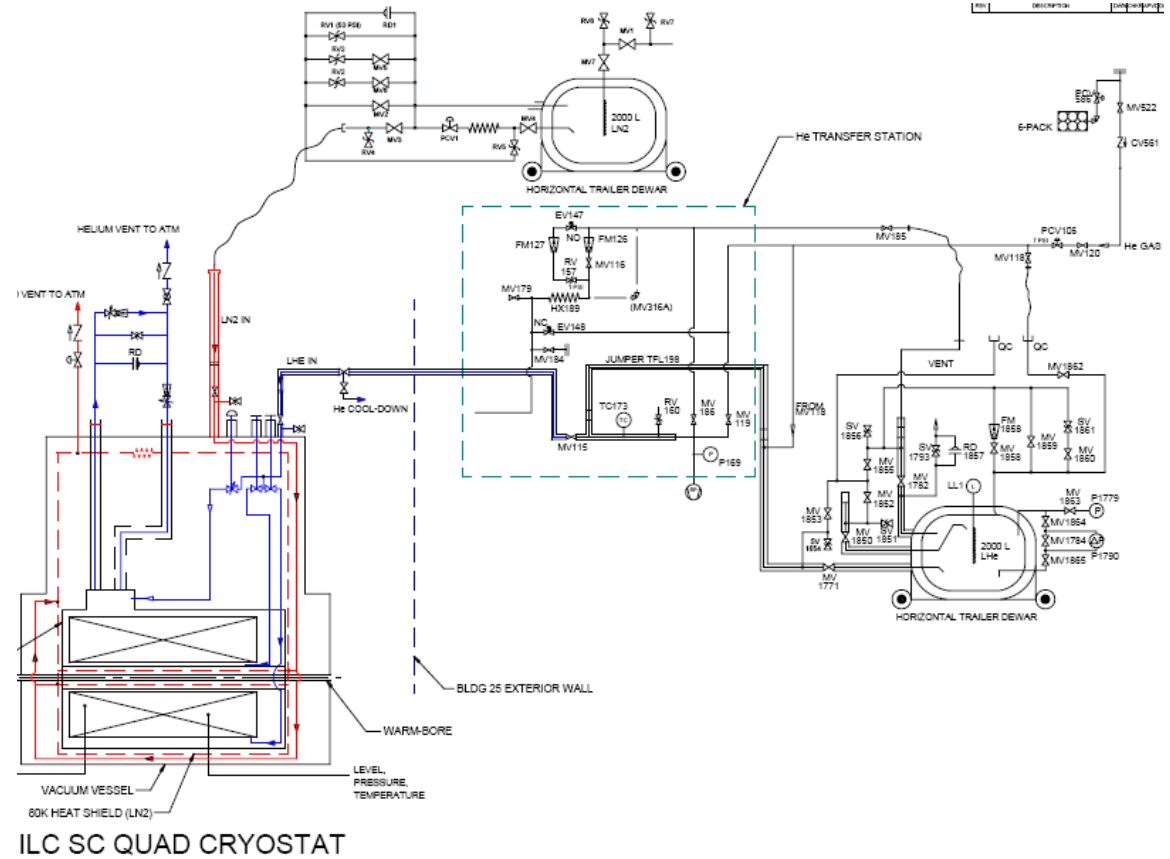
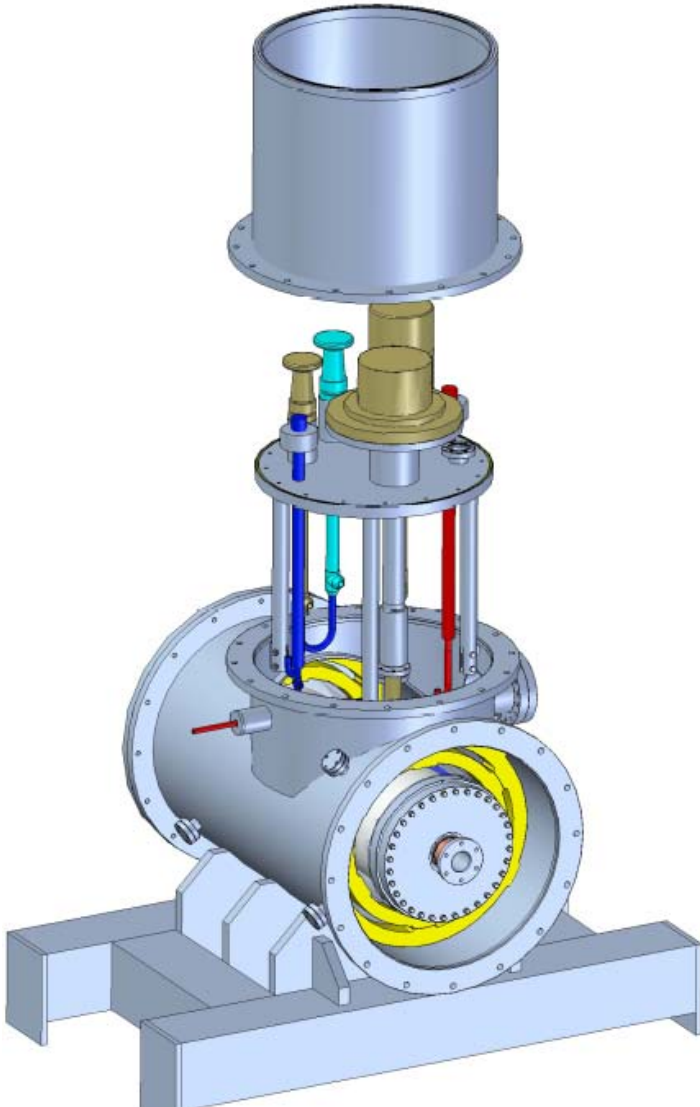
SC Coils

Iron Yoke
Block

Al Cylinder



Cryostat and Cryogenic System

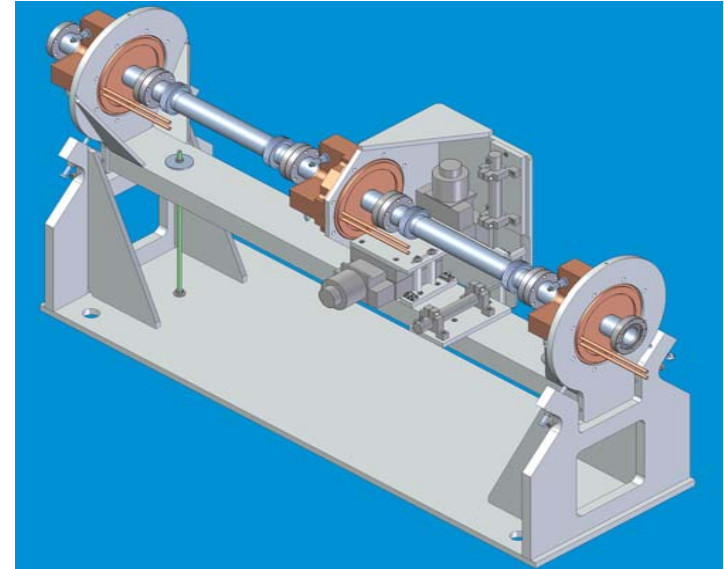
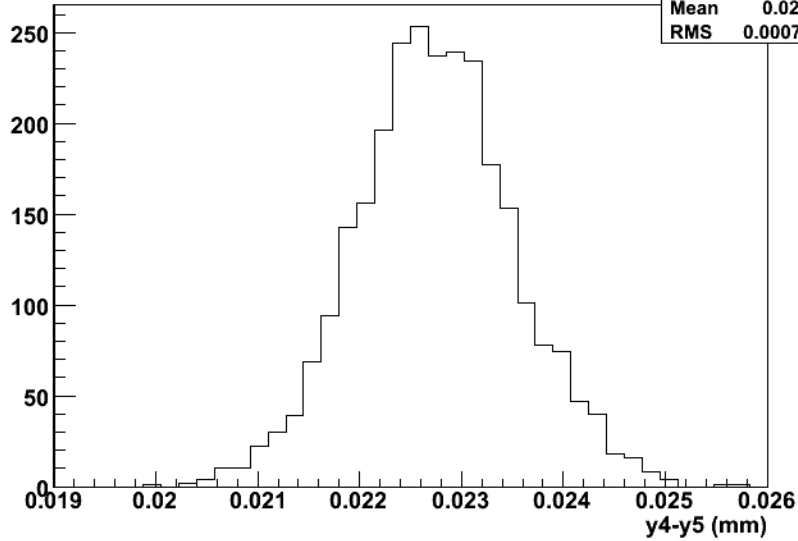


Recent BPM Triplet Results

(0.5 micron resolution, 1.4×10^{10} electrons, Q of 500 for clean bunch separation)

y4-y5, run 419

hy	
Entries	2702
Mean	0.02275
RMS	0.0007761



y4Pos:y5Pos {q41Amp>100}

