Fermilab Vertical Test Facility for ILC cavities

Vertical Cavity Test Facility (VCTF)

IB1 infrastructure

Future upgrades

Purpose of VCTF

- Test cavity quality (Q, Eacc)
  - Study cavity production and processing (i.e., S0 goals)
  - Cavity acceptance test prior to cryomodule assembly
- Develop Fermilab SCRF expertise
  - Contribute to world effort
  - Apply to new projects
- Technology transfer to university groups, other labs, industry
- Validate ILC project costs & technical performance

VCTF Initial Project Scope

- One Vertical Test Stand (VTS) in Industrial Building 1
- Single, bare 1.3 GHz 9-cell Tesla-style cavities
- Measure Q vs. T (T_{min}~1.5 K)
- Measure Q vs. E_{acc} at 2 K
- 250 W (CW) max RF power required

  $Q>5x10^9$ and Eacc<35 MV/m

  or $P_d = (1.04 \times 10^{-3}) * E_{acc}^2/Q_0 < 250$ W
- Use existing IB1 cryogenic capacity ~125 W at 2 K
  - 250 W for short periods without excessive bath temp increase
- Maintain “Controlled Area” status in IB1
  - ✓ < 5 mrem/hr immediately outside the shielding
  - ✓ <0.25 mrem/hr in normal working areas

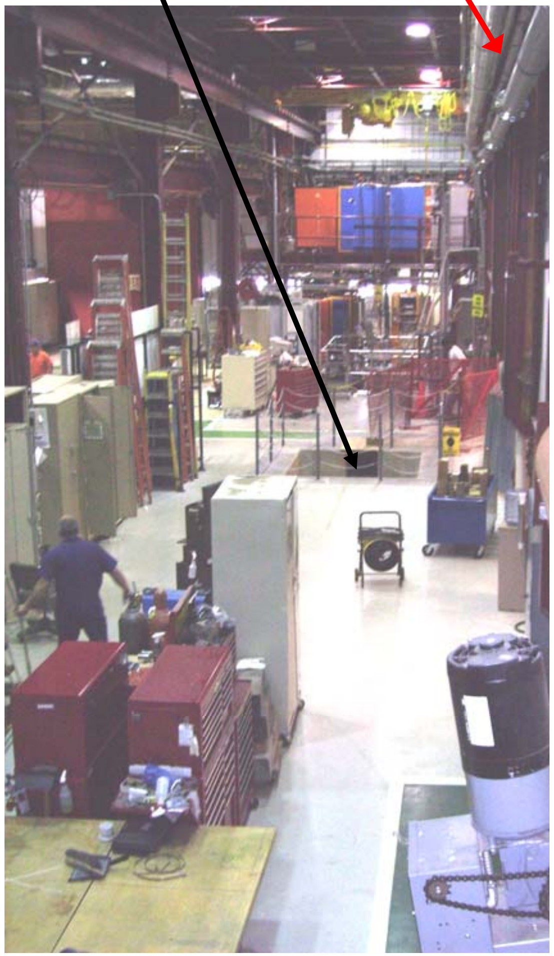
VCTF in Industrial Bldg 1

Existing IB1 cryoplant/infrastructure for Magnet Test Facility (MTF)

- Significant cost savings and faster implementation
- Capable of delivering LHe to the test stand at a peak rate of 700 liters/hr and
- Maintaining a bath temperature of 2K with up to 125 W of continuous power dissipation (250 W for short periods w/o excessive bath temp increase)
- Knowledgeable technical staff

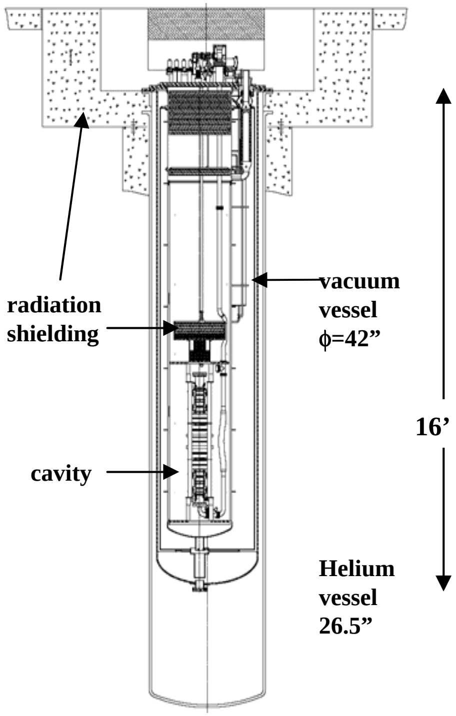
VTS pit

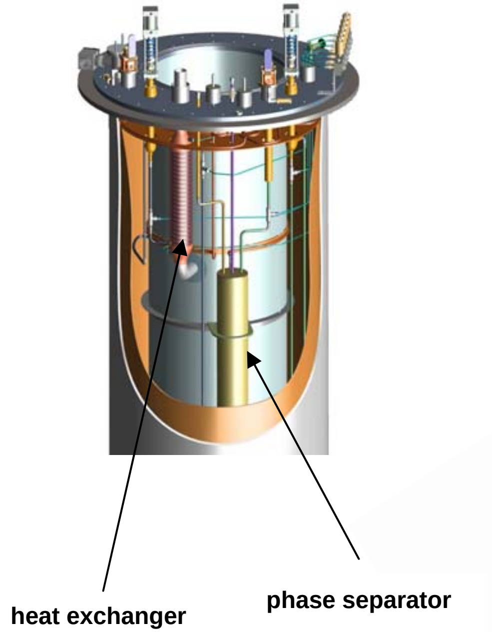
Existing cryogenic utilities & vacuum lines



VTS Cryostat/Insert Design

Based on Fermilab design of DESY/TTF/VTS
Added phase separator for better quality He





Cryostat under construction at PHPK Technologies, Columbus OH
Current schedule – complete end February 2007

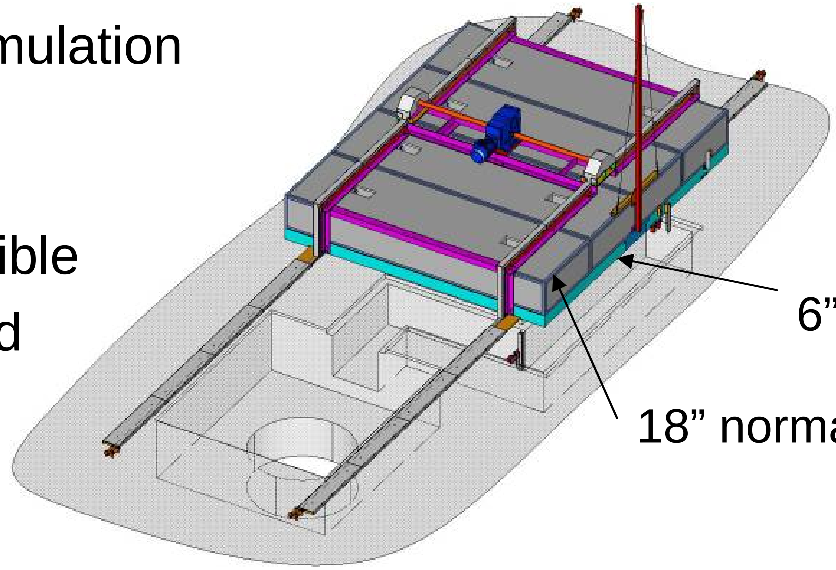
Magnetic Shielding

- Surface resistance increases due to trapped magnetic flux in localized normal-conducting surface impurities
- Magnetic field at IB1 floor in pit region measured to be consistent with Earth's magnetic field (~0.5 G)
- Two-layer design:
  - Outer RT cylindrical shield, attached to pressure vessel OD
    - Amumetal (80% Ni alloy) 0.040" thick
  - Inner 2K cylindrical shield, attached to helium vessel ID, with perforated (for LHe flow) endcap
    - Cryoperm 0.040" thick
  - <0.01 G at cavity, with significant safety margin
  - Both "permanently" installed in/on cryostat to avoid damage
- Under construction at Amuneal Manufacturing Corp., Philadelphia, PA

  Current schedule – complete end February 2007

Radiation Shielding

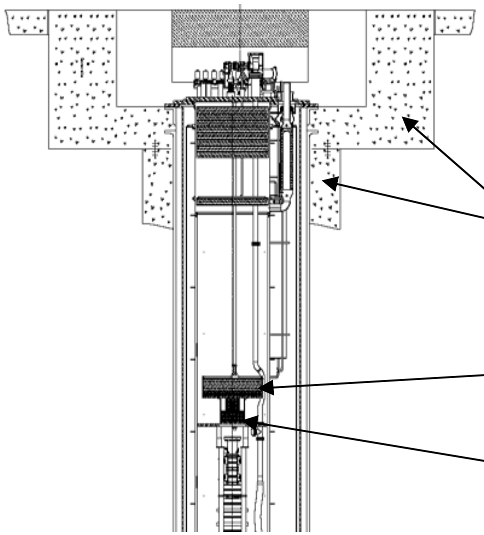
- X-rays estimated from DESY data
  Thanks DESY staff!
- Design from MARS15 simulation approved by ES&H
  (Fermilab-TM-2350-AD)
- Tritium production negligible
- “Controlled area” satisfied
- Parts being ordered



6” steel

18” normal concrete

Additional borated poly at instrumentation trench opening (not shown)



normal concrete

borated polyethylene, steel

lead

RF System

- Based on proven Jefferson Lab VTS RF system with technology advances
- Proven JLab LabView-based data acquisition system
  - Very user friendly – useful when we have visitors at test stand
- Collaboration with Jefferson Lab established (T. Powers, C. Grenoble)

  added to Jefferson Lab MOU
- Internal Fermilab review August 24, 2006 – all reviewers' recommendations incorporated
- RF personnel safety interlocks design approved by ES&H
- All parts received – in an advanced assembly stage

Control room and instrumentation

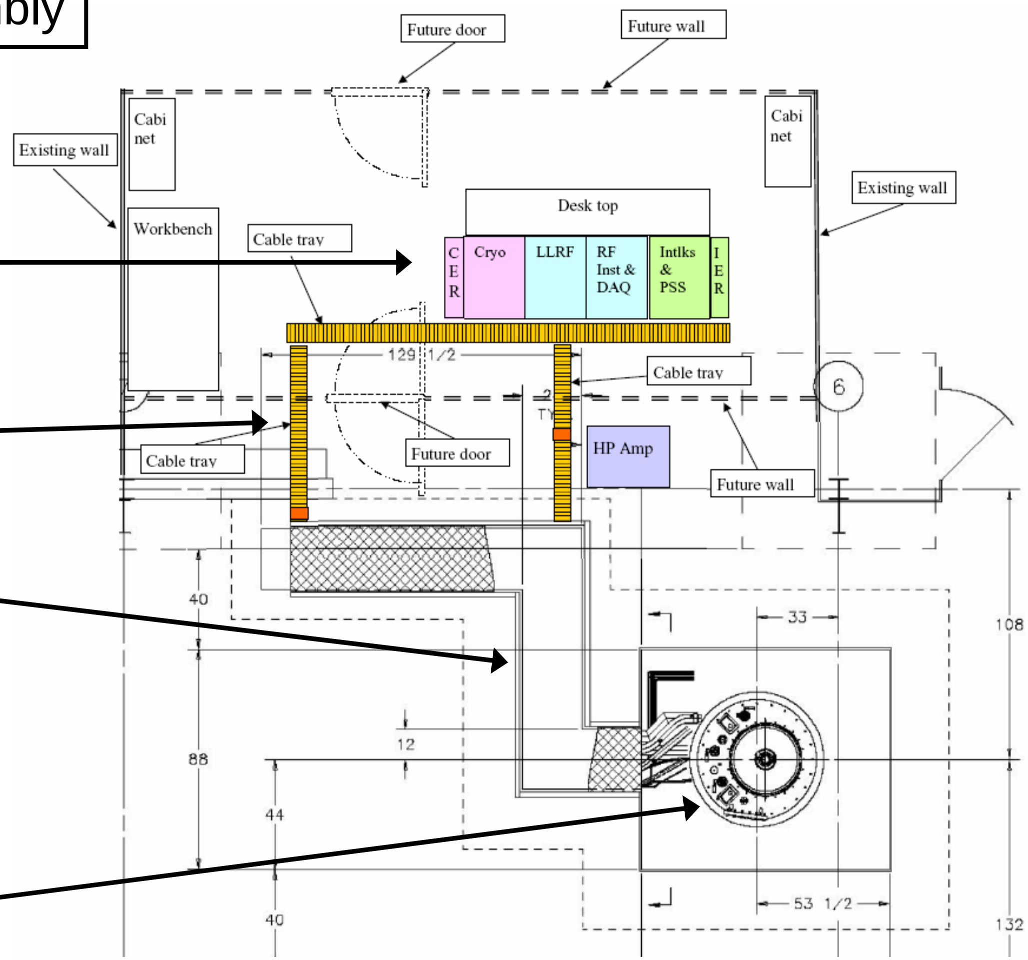
Under preliminary assembly

Control room

Cable trays

Instrumentation trench

Cryostat



Parasitic research goals

- Anticipate having a “diagnostic” top plate insert, ready to go when high-throughput cavity tests are paused
- Program will evolve depending on outcome of ongoing R&D. Current proposals:
  – Thermometry for quench location in 9-cells
  – Field emission studies with x-ray detectors
  – Systematic study of magnetic field on cavity performance
  – Single-cell studies (processing techniques, large grain Nb, other materials, other cavity shapes)
  – “Collaboration” established and developing with Fermilab PPD scientists with instrumentation experience. Anticipate involving others.

Single VTS Throughput

Task	Duration (hours)
Receive cavity and cage	0
Mount cages to insert	1
Connect cables and TDR test	1
Install insert in dewar	1
Perform Dewar seal check	0.5
Perform Dewar leak check	1
Backfill Dewar, helium contamination check	0.5
Cooldown to 100K, 8 g/sec	0.5
Wait at 100K for 8 hours (for Q-disease study)	8
Cooldown to 4K	1
Fill @ 4K	2
Pump to 2K	3
RF Test at 2K	**4**
Boil off LHe	4
Warmup Dewar	17
Remove insert	1
Remove cavity cage from insert	1
Total single-cavity test cycle duration	**46.5**

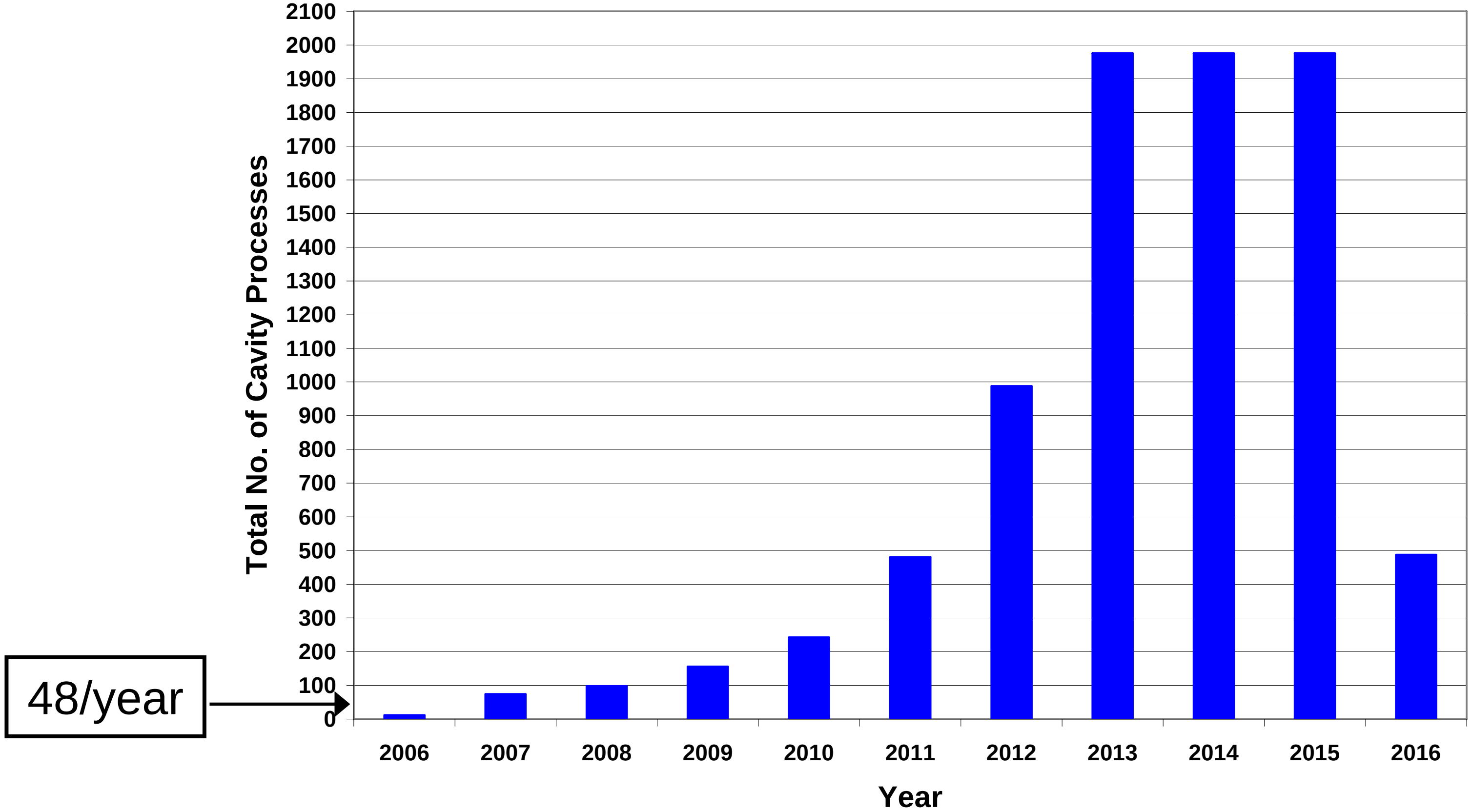
46.5 hours becomes 5 days with current infrastructure, primarily from waiting for people to become available

Single VTS Throughput (cont.)

IB1 Cryogenic System Downtime	60	days
IB1 Vacuum Pumps Unavailable	24	days
LHe Inventory Unavailable	12	days
VCTF Unavailable	15	days
TOTAL EQUIPMENT UNAVAILABILITY	111	days
HOLIDAYS	10	days
VTS Test Cycle (incl. shift operations)	5	days
Number of Test Cycles in a Year	**48**	

Projected Annual # Cavity Tests for S0

(from S. Mishra, ART FY08-09 Planning Meeting at SLAC 9/13/06)

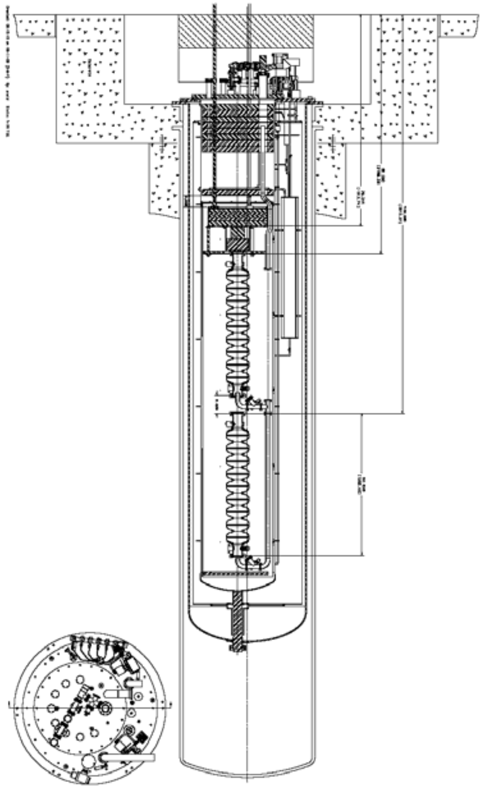


Required capacity exceeded in first couple of years

Add vertical test throughput

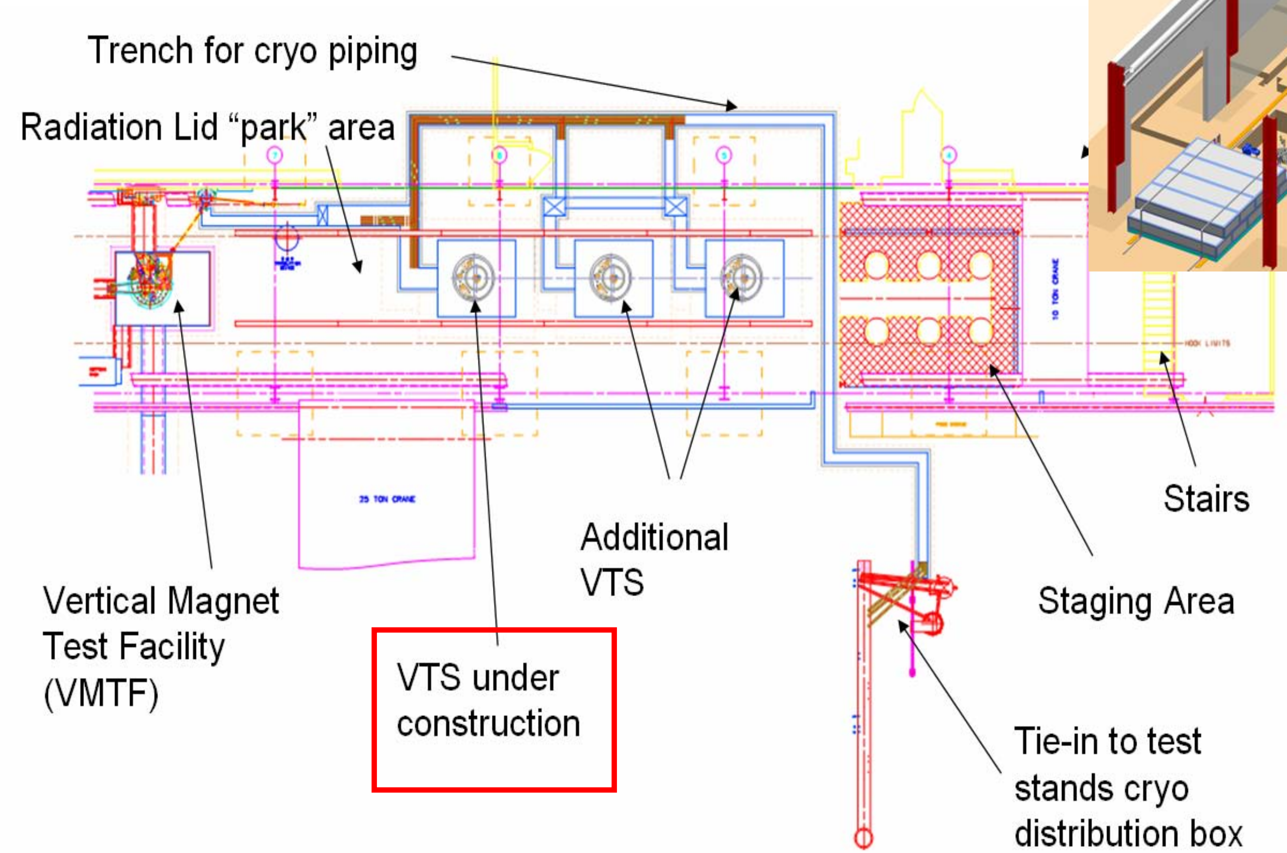
- Upgrade VTS for two-cavity operation
- Add two more vertical test stands to VCTF
- Upgrade cryogenic infrastructure

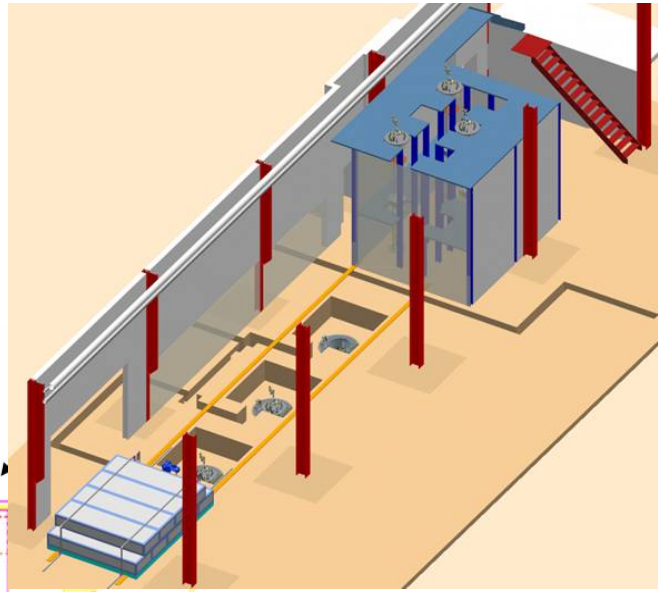
Two-cavities in VTS



- Single most effective way to increase throughput
- RF test one cavity at a time
- RF portion of cavity test <10% of test duration, can substantially increase throughput by cooling/warming two cavities simultaneously
- 5 days -> 6 days total test cycle duration
- VTS spatially accommodates two cavities
- Radiation shielding sufficiency to be determined, but should be possible with minimal upgrades
- Increases to 80 test cycles/year (almost factor 2)

Two add'l VTSs and staging area





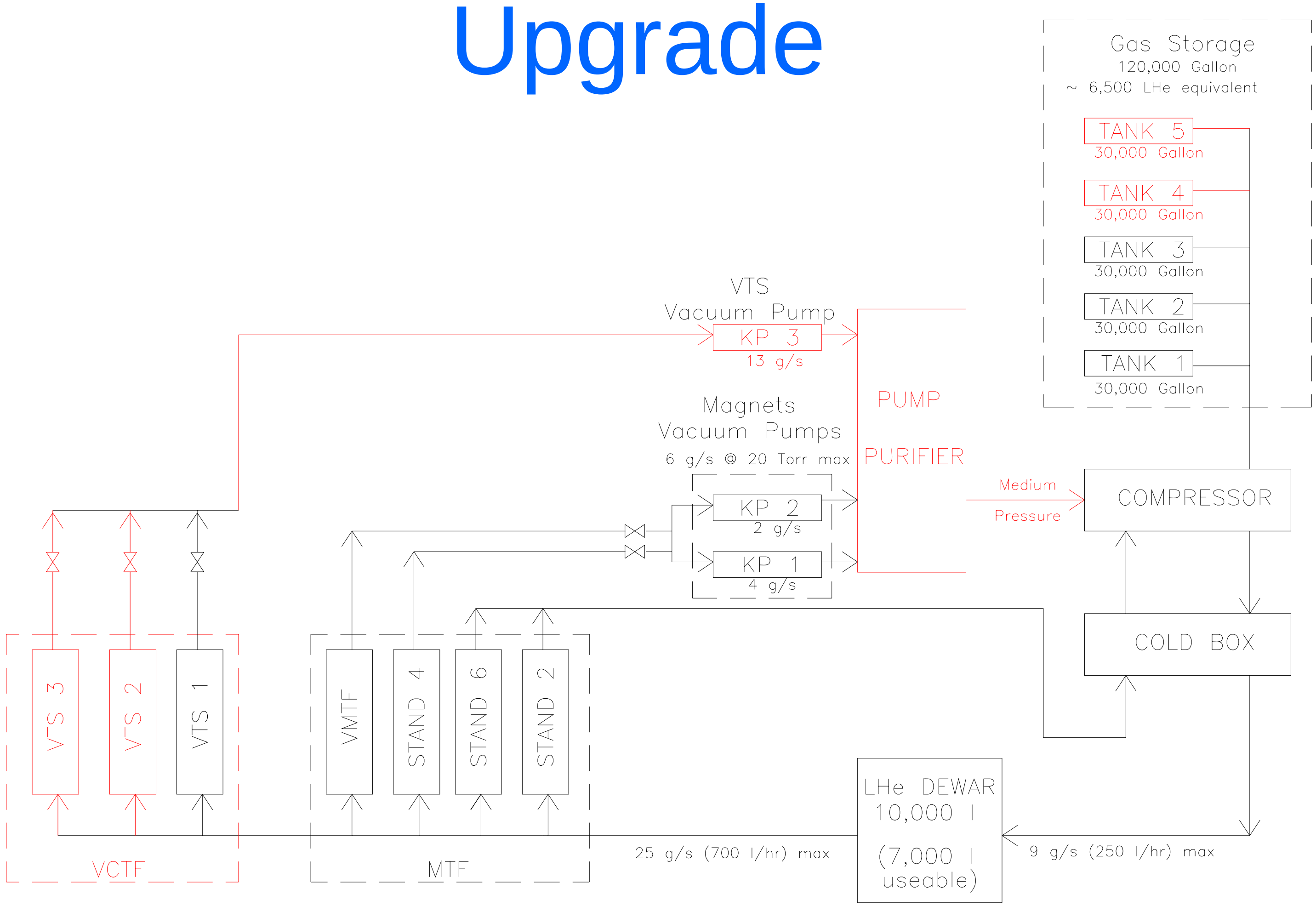
Two add’l VTSs and staging area

- RF testing still one cavity at a time (not strong constraint)
- Common RF/DAQ system (except RF amplifier)
- Staging area to accommodate 6 top plates, each supporting two cavities
- As similar as possible to first VTS to minimize civil/mechanical/radiation shielding design and procurement costs
- ~180 tests/year (cryo system risk limited…)

VCTF Cryogenic Infrastructure Upgrades

- *Reduce schedule risk by adding safeguards to reduce downtime*
  - Add compressor and full-flow purifier skid at vacuum pump outlet to eliminate contamination from sub-atmospheric operation (primarily air-leaks)
- *Decouple vertical cavity testing from superconducting magnet tests.*
  - Install dedicated vacuum pump for cavity vertical tests to de-couple from superfluid magnet tests
  - Add dedicated 10-ton crane
- *Add helium gas storage capacity and staff to accommodate three VTS cryostats*
- *All upgrades require additional transformer*
- ~264 cavity tests/year

Proposed VCTF Cryosystem Upgrade



Infrastructure Scenarios

Scenario	IB1 Cryo system status	as-is			upgrade		
	#VTS cryostats	1		3	1		3
	#cavities in all available VTS cryostats	1	2	6	1	2	6
Downtime cause							
Cryo down		60	60	90	45	45	45
Pumps unavailable		24	24	36	0	0	10
LHe supply unavailable		12	12	20	0	0	10
VTS unavailable		15	15	25	15	15	25
holidays		10	10	10	10	10	10
Total down days		121	121	181	70	70	100
VTS test cycle		5	6	6	4	5	6
# tests		**48**	**80**	**180**[1]	**73**	**118**	**264**

[1] Scenario carries considerable risk because lack of purification system to remove contamination introduced by three sub-atmospheric test stands could significantly increase cryogenic system downtime.

Cost Summary

Infrastructure	**M&S ($)**	**SWF (FTEs)**	**SWF ($k)**	**Total with Indirect ($k)**
VTS-1 (FY07 to complete)	651	13.1	1769	2913
VTS-1 (w/ 2 cavities)	75	1.0	135	256
VTS-2 and -3	1300	6.7	900	2752
Cryogenic system upgrade	1251	6.0	810	2582

Conclusions

- Vertical Cavity Test Facility with one Vertical Test Stand well underway, to be operational in FY07
  - Will establish Fermilab as an ILC cavity testing facility
- Infrastructure upgrades required to
  - accommodate more cavities to maximize cavity throughput, and
  - advance SCRF technology
- Develop Fermilab SCRF expertise
  - Develop collaborations on cavity diagnostic instrumentation for SCRD R&D
  - Apply advances to new projects
- Technology transfer to university groups, other labs, industry
  - SCRF R&D effort
  - Accommodate visitors with user-friendly facility