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IB1 Cryogenic Facilities and Operations

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Mini-Review of Fermilab Accelerator Test Facilities Program

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Outline

- This talk will cover
  - Scope and cost of cryogenic, vacuum, air, water, power, controls, instrumentation, Data Acquisition (DAQ), and administrative operational activities, necessary for the support of all magnet and SRF testing in the Industrial Complex

T&I Mission

- The mission of the Test and Instrumentation (T&I) Department is to:
  - Manage, operate, maintain, and develop the Technical Division's Magnet Test Facility (MTF) and Vertical Cavity Test Facility (VCTF), both located within the Industrial Building 1 (IB1) sharing infrastructure and services
  - Support users of these test facilities to conduct tests and acquire measurements of both R&D and production conventional and superconducting magnets and superconducting RF cavities
  - Develop advanced instrumentation and provide instrumentation fabrication services to test facilities and Technical Division projects.

T&I Department

M. Tartaglia – Head
C. Sylvester – Deputy Head
(R. Carcagno)

K. Ohman

Area Leaders
Magnet Test
D. Orris

Cavity Test
R. Pilipenko
(O. Melnychuk – SRFD Liaison)

Test Coordination
(D. Orris)

Cryogenic Engineering and Operations
R. Rabehl

A. Hemmati
S. Koshelev
(B. Squires)

Operations Support
B. Squires

G. Kirschbaum
D. Marks
R. Milholland
R. Ward
F. Wilson

Mechanical Engineering
(C. Sylvester)

C. Hess
L. Kokoska
A. Vouris

Mechanical Technical Support
(opening)

M. Thompson
T. Zolli
(opening)
(opening) (C)

Instrumentation and Controls
(D. Orris)

M. J. Kim
A. Makulski
R. Nehring (*)
(R. Pilipenko)
A. Yuan
A. Galt (G)
(* opening)

Electrical Technical Support
F. Lewis

W. Andrews
P. Dubiel
D. Eddy
H. Bruch
(opening)
R . Smith (C)
A. Irigoyen (C)
K. Kompiel (C)

Software Systems
J. Nogiec

S. Kotelnikov
D. Walbridge
K. T-Freytag
P. Akella
R. Duszak (C)

Multi-disciplinary teams support facility operation, maintenance, repair, improvements. Core competencies align with laboratory project needs

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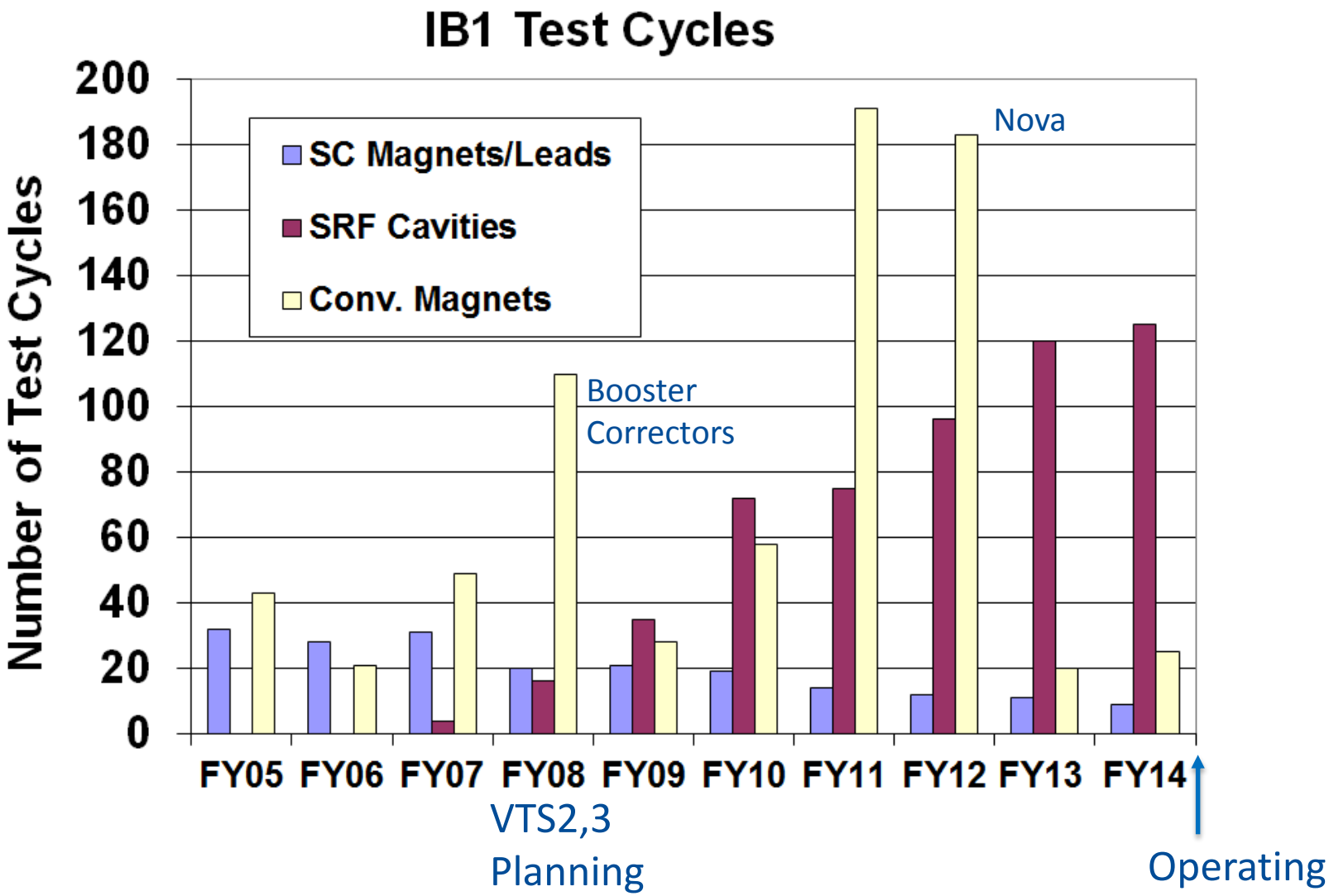
Operations Test History



Test Program Diversity

IB1 Test Cycles [TC] (From October 2010 to February 2015)

Project \ FY	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
LARP	HQM01 LQS02 HQM02	HQM04 LQS03 [1 TC]	LQS03 [1 TC] HQ02 HQ02A2	LHQM01	HQ03a
HFM	LQM01 [2 TC]	TQC03Ea [2 TC] MBHSP01 [2 TC]	TQM05 [2 TC] MBHSP02	MBHSM01 MBHSP03	MBHDP01
MICE			MuCool-01 [2 TC]	MuCool-01 [1 TC]	
Mu2e	Mu2e_SOL_01	HTS Power Leads Qualification: Test of TSHH271 At TS-4/TS-6 Test Stand 3 Restoration	HTS Power Leads Qualification: L2161_L2162 [2 TC] L2583_L2584 [3TC]	HTS Power Leads Qualification: L2583_L2584 [2TC] L2575_L2577 L2585_L2576* L2585_L2158 L2582_L2579 (*L2576 isn't qualified for Mu2e use)	
Muon Collider	HSM02 [2 TC]				
ILC	CM2_Dipole_02 ILC_RTQ_02 [2 TC]	ILC_RTQ_02 [2 TC]	ILC_RTQ_02-1		
LCLS-II					ILC_SSQD_02 Piezo_Test_Picma
HINS	HCHB01 Zero Magnet Test	SS2_SOL_01d			
Project X				PXIE_SSR1_L01P [2 TC]	
RTD Calibration Run	Calibration Cycle #1	Calibration Cycle #2, #3	No Calibration Cycle	Calibration Cycle #4, #5, #6	Calibration Cycle #7
SRF – 1.3 GHz	~ 75	~ 90	~ 100	~ 100 (120)	~ 19 (30)
SRF – non-1.3 GHz		~ 5	~ 20	~ 5	~ 4 (8)
Conventional Magnets	~ 200	~ 200	~ 20	~ 25	~ 28

T&I Department Major FY15 Tasks

- **VCTF**
  - √ Upgrade Radiation Shield Rails
  - – Upgrade VTS Crane Coverage
  - ⁘ Add 3.9 GHz RF power and instrumentation capability to VTS 2
  - – Support Cavity Testing (325 MHz, 650 MHz, 1.3 GHz, 3.9 GHz)
- **LCLS-II**
  - ⁘ Specify, Procure, Install and Test LCLS-II Prototype Cryomodule Instrumentation
  - ⁘ Support New Instrumentation for VCTF, HTS, STC, CMTF, and LLRF microphonics studies
  - ⁘ Test Short Splittable Quadrupole (ILC-style, two LCLS-II Prototypes)
- **PIP-II**
  - – Support 650 MHz high Q_0 and SSR1 solenoid test programs
- **MAP**
  - ⁘ Complete replication, minor upgrades, and packaging of MICE SS Quench Detection System
- **Mu2e**
  - ⁘ Upgrade CHL Solenoid Test Facility for testing mu2e prototype solenoids
  - – Test TS Prototype Solenoid Module
  - – Test Toshiba Coil (and DS welded bus splices)
  - – Complete design of SolTF permanent thermal shield and design modifications for production TS module testing
  - – Progress towards final design of Quench Protection and Monitoring, Cryo Controls, DAQ and Instrumentation
  - – Complete preliminary design of solenoid Field Mapping DAQ & Controls system
- **LARP**
  - ⁘ Complete Upgrade of VMTF 30 kA Top Plate for superfluid operation, larger aperture, and CLIQ protection leads
  - – Test SQXF Mirror and Quadrupole prototype magnets in VMTF
  - ⁘ Complete SELVA winding machine controls upgrade
  - – Assist with Cold Mass and Tooling Design; Begin Stand 4 upgrade design for testing LARP HiLumi quadrupoles
- **HFM/11T Dipole**
  - – Test dual aperture prototype 11 T dipole
- **Accelerator Support**
  - ⁘ Support conventional magnet testing
  - – Measure APS-II prototype gradient dipole

T&I Department Major FY15 Tasks

- **IB1 Systems maintenance and improvements**
  - √ Complete Conventional Power System Interlocks and Controls upgrade (Stand A)
  - – Acquire & Install Generator and Automatic Transfer Switch for Critical Computing Systems
  - – Complete development of SSW measurement system (version for KEK)
  - – Complete development of ADC/FPGA-based integrator for SSW and rotating coil measurement systems
  - – Continue development of EMMA framework, toward retiring Sun Sybase computer from operations (archive database)
  - – Commission EMMA Point Scan Calibration System
  - – Complete migration from WindowsXP (DAQ machines) to Windows7
  - – Begin design of VMTF/Stand 4 Instrumentation upgrade (start late FY15)
  - – Construct new Isolation Amplifier Chassis for Stand 4 and VMTF
  - – Complete development and begin deployment of new power supply regulator and controller

  - √ Perform annual plant maintenance; tie in suction line to new purifier system
  - √ Complete iFix controls system upgrade and migration to new SCADAs and SERVER
  - – Install a more efficient over-the-roof LHe transfer line (already procured and delivered) [During Next Maint. Shutdown]
  - ⁘ Complete Safety Review, Commission and start operations of IB1 Cryo Upgrades (Hard Stand, Mycom compressor, new purifiers)
  - ⁘ Install a helium gas recovery pipe between TD and CHL
  - ⁘ Continue engineering studies of Liquid Helium Sources and Utilization

  - – Replace turbine cooling water chiller (? Depending on Engineering Resource Availability)
  - – Procure/Install New compressed air dryer (? Depending on Engineering Resource Availability)
  - – Upgrade cold box vacuum system [During Next Maintenance Shutdown]
  - – Refurbish old Kinney Pumps I and II (needed for Stand 4 testing of HiLUMI magnets)
  - – Assemble new vacuum pump cart
  - – Improve and automate RTD Calibration Facility

  - √ Provided Unanticipated support of Cavity Tuning Machine for DESY XFEL; anticipate CTM maintenance at FNAL

Air and Water Utilities Scope - 1

Main functions

- Compressed Air
  - Tools for IB1, IB2
- Industrial Cooling Water (ICW) System
  - Process Equipment (Compressor Motors, Kinney Pump Motors)
- Low Conductivity Water (LCW) System
  - Power Supplies
  - Resistive Bus and Magnets

IB1A, extension, and GHe tube trailer

LCW, ICW, Compressor Skid in IB1A

Air and Water Utilities Scope - 2

Main Components

- Compressed Air
  - 2 compressors, filters
- ICW
  - Glycol Heat Exchanger
  - Adams Filter
  - Chiller (summer operation) new 2008
- LCW
  - Reservoir, Piping
  - 2 Main Pumps
  - 2 Local Booster Pumps
- Sensors and PLC Controls [very old]

New Chiller in IB1A

New GHe storage tanks

Cryogenic Plant Scope - 1

Main functions and systems

- Liquify Helium to 4.5 K
  - 1st & 2nd stage compressors (IB1a)
  - Cold box with Pre-cooler
  - 2 Turbines
  - 10000 Liter LHe storage dewar
  - 10000 Gallon LN2 storage dewar
  - Insulating vacuum system
  - Sensors and PLC Control System
- Systems for <2K Operation
  - 4 new Kinney Pumps (2012)
  - 2 old Kinney Pumps

IB1 LN2 dewar and transfer lines

Operational Kinney Pumps in Midway Area

Cryogenic Plant Scope - 2

Main functions and systems

- Distribute LN2, LHe
  - Distribution Box
    - Horiz. stands 2, 3a/3b, 6
  - Over-the-roof Transfer Line
    - Vert. stands VMTF, VTS-1,2,3
  - Local transfer lines, valves
- Recover, Store & Purify GHe
  - 3 old + 4 new (2010) Buffer Tanks + piping
  - Contamination Monitors; 2 old Purifiers
  - Mycom Compressor, 2 new Purifiers (2010-now)
  - Tube Trailers (Hard Stand for GHe inlet)
  - VMTF Quench GHe Recovery (2012)
  - IB3a/IB1/CHL GHe Recovery Line (2015)

Two new purifiers for GHe recovery

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Process System Operational Expenses

Personnel

- Cryogenic, Mechanical
  - Engineering, Safety & Group supervision
- HA, Documentation, Training
- Calibrations
- Plant and Test Stand Operation
- Equipment repairs & maintenance
- Improvements
  - reduce risk, increase efficiency, reliability, capability

Materials and services

- Consumables
- Repairs and maintenance
- New and replacement equipment

Power Systems Scope - 1

Main functions and systems

- AC Power
  - Distribution & Monitoring
    - 110/208/480 VAC
    - Specification, Procurement, Coordination, Oversight
  - Electrical Safety
    - HA, Procedures, Training
- Magnet Power Systems
  - High and Low V,I Power Supplies
    - AC, DC, Pulsed
  - Bus-work, Energy Extraction
  - Interlocks, Personnel Safety
  - Device Safety Evaluation
    - Stored E, Cooling Requirements

New 1500 KVA transformer installed 2010

New switchboard and Compressor Soft Motor Starter installed in IB1A, Power Panel installed in Kinney Pump Room

Power Systems Scope - 2

Main Components

- AC Power
  - 2 1500 KVA Transformers
  - UPS units
- Magnet Power Systems
  - Conventional Magnet Meas.
    - 3 Stands
    - 5 kA, 10kA (4PEIs); Trim PS
      - Interlock Upgrade FESHM compliance (2014)
    - 15 Hz Booster Corrector PS
  - Kicker/Pulsed Magnet PS
  - SC Magnet Testing
    - 10 kA TransRex PS + Dump (Tevatron St 2,6)
    - 30 kA (6 PEIs) + Configurable Dump (VMTF, St 3, St 4)
    - 2 Portable Systems (3 330A Lambda PS + Configurable Dump)

Power Systems Operational Expenses

Personnel

- Engineer & Technicians
- HA, Documentation, Training
- Calibration
- Equipment repair & maintenance
- Improvements

Materials and services

- T&M Electrical Contractors
- Calibration
- Repairs and maintenance
- New and replacement equipment

Instrumentation, DAQ & Control Systems Scope - 1

Main Functions and Systems

- Industrial Process Monitoring & Control Systems
  - Cryogenic Plant, Water Utilities: PLC/HMI
  - Cryogenic Test Stands: PLC/HMI, LabView DAQ, VME DAQ
- Power System Monitoring & Control
  - PLC/HMI, LabView DAC, VME DAQ
- Development/Maintenance of Many Specialized Systems
  - Needs of Projects and Programs (IB1-4, CHL, HTS, CMTF, …)
    - Magnetic Measurements (20-year old system replacement)
    - Quench Detection and Characterization (multiple generations, sites)
    - Sensor Monitoring Scan Systems (multiple generations, sites)
    - Splice Resistance, Energy Loss, Sc Voltage Spike Detection
    - Cavity Tuning Machine (2009-10) , SELVA Winding Machine (2014)
    - SRF & Cryomodule Instrumentation (multiple sites)

Instrumentation, DAQ & Control Systems Scope - 2

Main Components

- Process Control
  - Several generations, makers of PLCs
  - HMI - GE/Fanuc iFix/iHistorian (periodic product updates)
    - MS Windows Server + Clients
      - periodic Computer Hardware upgrades and OS migration
    - 2500 Process Variables and growing
    - Dozens of operator interface displays
      - Still some legacy systems that need modernization !
- Specialized (Multi-Disciplinary) Systems
  - Fixed Installations (Test & Measurement Stands)
  - Mobile/Portable Systems
    - Magnetic Measurements, Power & Quench Protection
- Network
  - Complex, aging architecture

Instrumentation, DAQ & Control Systems Scope - 3

Main Components

- DAQ, Instrumentation, Controls Computers
  - Sun Microsystems unix (10)
    - Conventional Magnetic Measurements and Sybase Data Archive
    - Test Stand Monitoring, Controls, Quench Detection & Characterization, Analysis, Data Archive
  - Test Stand VME processors (12)
  - Windows and LINUX Servers (7)
    - Process Control, Website, e-log, Data Archives
  - Windows PXI Controllers & PCs (14)
  - DAQ PCs and Terminal Servers (17)
- Software
  - C/C++, Java, LabView, Scripting (configuration)
  - Matlab, Simulink & other design/development tools

Calibration Facilities - 1

Main Functions and Systems

- Precision Magnetic Field Measurements
  - 2T GMW Calibration Dipole Magnet & PS
  - 5T Tevatron Dipole w/ 50mm Warm Bore Tube
- Low Temperature Sensor Calibrations
  - Cost Effective in-house RTD calibrations
- Material Calibration Test Facility
  - Result of Ph.D. project
  - Miscellaneous cryogenic device studies

Instrumentation, DAQ, Computing Operational Expenses

Personnel

- Engineering and Technicians
- HA, Documentation (SQA), Training
- Test Configuration, System Checkout, Data QA
- Development of Instrumentation Devices & Systems
- Calibration
- Equipment repair and maintenance

Materials and services

- Software licenses, Test Equipment, Tools
- Calibration
- Repairs and maintenance
- New and replacement equipment

Test & Instrumentation Summary

Facility	FTE	SWF K$	M&S K$	Total Direct K$	Total Loaded K$
Process & Mechanical Systems	7.00	716	298	1,014	1,690
Cryogens			400	400	492
Power & Electrical Systems	0.94	117	62	179	292
Instrumentation & DAQ	3.72	371	83	454	788
Computing and Software	1.13	144	71	215	354
SC Magnet Test Stands	2	200	135	335	536
Conventional Magnet Testing	0.10	17	10	27	43
Test & Instrumentation Management	2.99	326	60	386	677
Test & Instrumentation Subtotal	**17.88**	**1,890**	**1,119**	**3,009**	**4,874**

BACK UP SLIDES

Cryogen cost estimate FY15

The cost estimate for cryogens was provided by Ali Hemmati from TID. It includes purchases of liquid nitrogen and of helium, both liquid (LHe) and gas (GHe). Note that in the FY13 and FY14 roughly half the cost of the cryogens was included in Project 18 operations. We are constantly striving to reduce the leakage of Helium through improvements to the system, but the liquid nitrogen is a consumable.

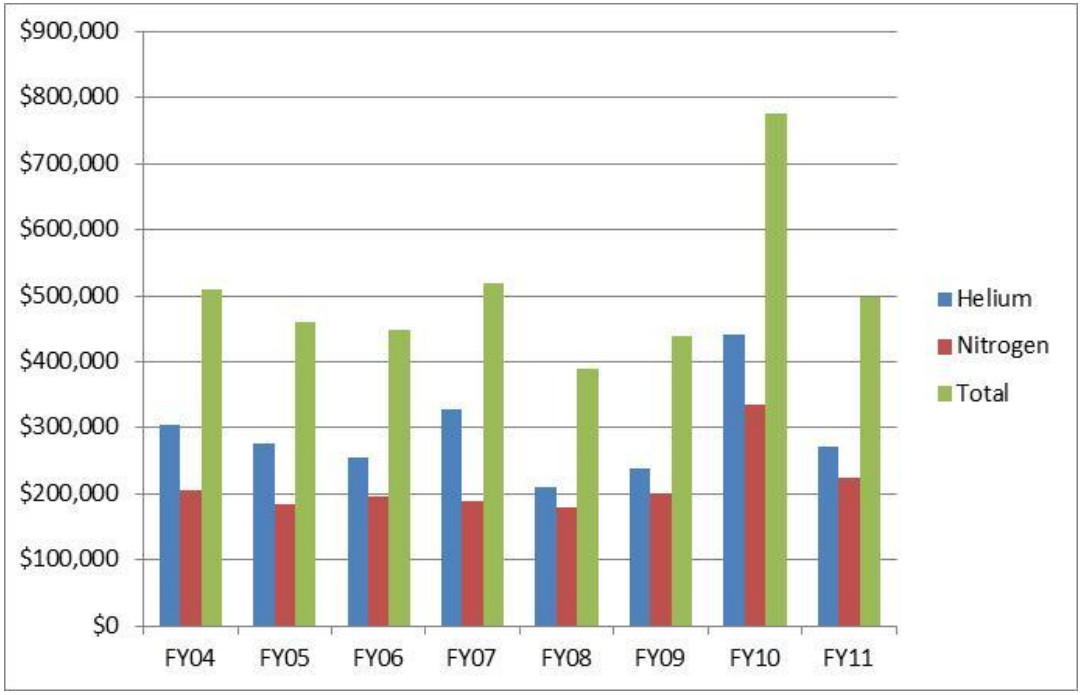
The estimate is based on actual Helium losses averaged over last three years; some decrease may be expected once the new purifier is online (e.g., no dumping of contaminated Kinney pump flow), but this is not guaranteed. We assume the current LHE price from Linde (could increase with new contract). The price of GHe from PraxAir (if we use Hard Stand tanker) could be higher.

Because we are expecting additional operational capabilities of VTS 2 and VTS 3 to be used by LCLS-II and PIP-II, we add 7% to helium consumption and 30% to the Nitrogen usage to arrive at our FY15 estimate. The estimated increase is based on a study we did in 2011 which is summarized in document TID-N-307.

Cryogen	Historical rate	Estimated Increase for FY15	FY15 Estimate
Helium	$ 600,000	7%	$ 642,000
Liquid Nitrogen	$ 132,000	30%	$ 172,000
Subtotal for Cryogens			$ 814,000

Increase of LN2 use is delayed

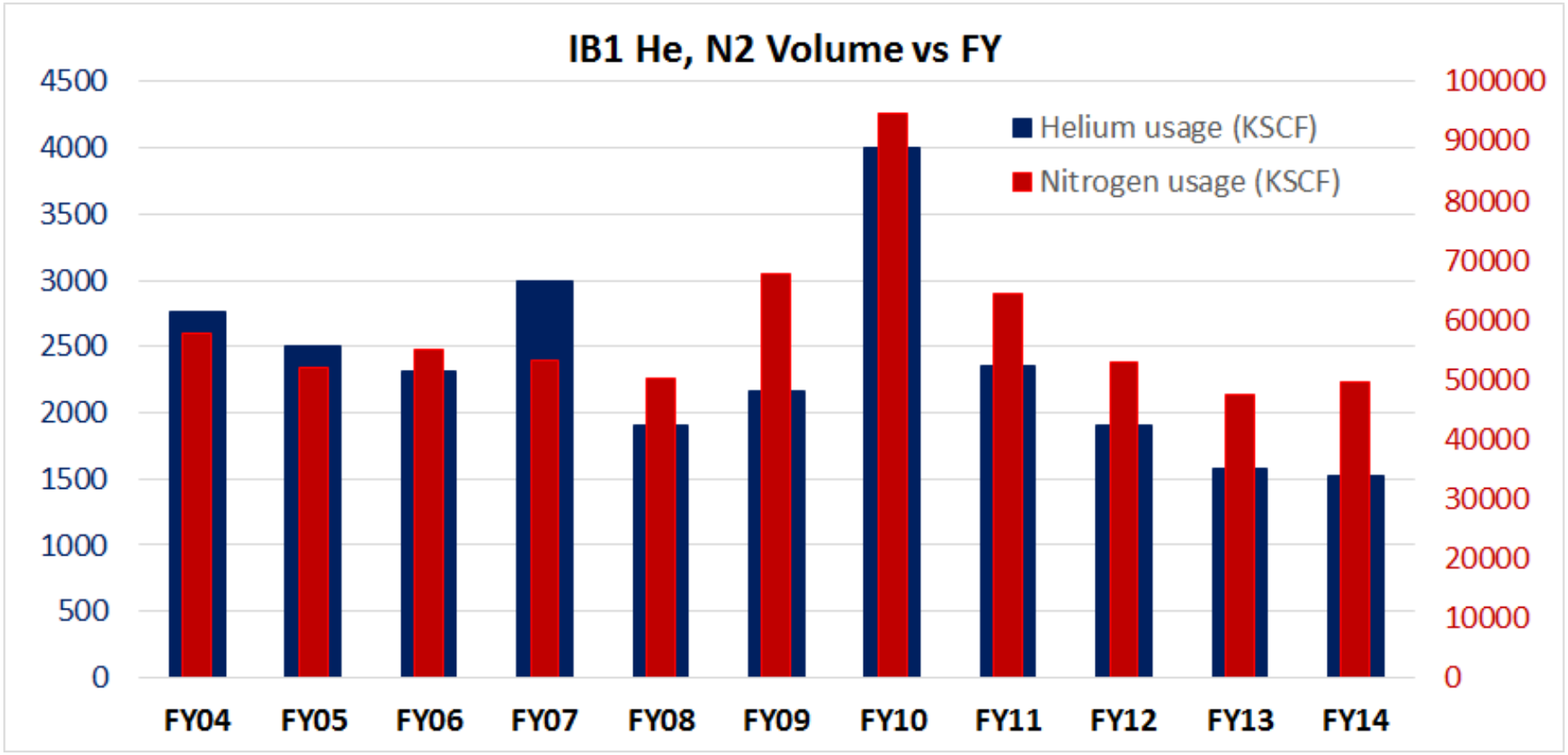
IB1 Cryogen Usage (2011 Study)



- **Average ~ $500K/year, 60% He and 40% N2**.
- FY10 $800K spike due to venting losses during long LARP magnet testing plus pump, purge, and filling new gas helium storage tanks

- Needed to support **100** superconducting test cycles for cavities and magnets and for commissioning of new equipment:
  - VTS 2&3
  - MICE cryostat
  - New Kinney Pump room
  - Mycom compressor/purifier
- **Cost of helium expected to increase substantially after the 5-year Fermilab contract expires in Nov. 2011**
- **New IB1 equipment will consume ~ 30% more Nitrogen**
- A detailed IB1 Cryogen Usage study was conducted in FY11 and documented in TID-N-307

IB1 Cryogen Usage (2014 Update)



Process System Maintenance

System	Frequency
Cryoplant	
Remove LB165 oil and replace	yearly
Change 1st and 2nd He Compressor Oil filter	yearly
Inspect He skid field devices	yearly
Inspect Controls cabinet wiring	yearly
Replace PLC's internal battery	yearly
Change oil and inspect diffusion pump	yearly
Inspect cold box roughing pump belts, replace if necessary	yearly
Inspect distribution box roughing pump belts, replace if necessary	yearly
Change cold box roughing pump oil	yearly
Change distribution box roughing pump oil	yearly
Check vibration for Compressors and motors	quarterly
Blow down Balston oil removers	monthly
Blow down charcoal absorber	monthly
Blow down final filter	monthly
Blow down valve before final filter	monthly
Rotate shaft on spare compressor	monthly
Grease motor bearings	every 2000 hrs
Warm Cold box to 100K	as needed
Check operation of ODH monitors	monthly
Water Glycol	
Clean ICW to glycol heat exchanger	yearly
Clean ICW to LCW heat exchanger	yearly
Clean ICW to evaporator heat exchanger	yearly
Clean Adams filter and change filters	yearly
Grease LCW pumps bearing	monthly
Grease glycol pumps bearing	monthly
Grease evaporator pump bearing	monthly
Power rod chiller condenser	as needed
Power rod chiller evaporator	as needed
Kinney Pump	
Grease Kinney 1 ring pump	every 1500 hrs
Grease Kinney 1 ring pump motor	every 1500 hrs
Grease Kinney 2 ring pump	every 1500 hrs
Grease Kinney 2 ring pump motor	every 1500 hrs
Grease Kinney 2 booster motor	every 1500 hrs
Add oil to Kinney 1 booster pump	as needed
Change cooling water filter cartridges	as needed
Air Compressors	
Change Oil and filter	as needed
Clean radiators	as needed
Purifiers	
Derime	as needed