12 GeV Upgrade of Cryogenics at Jefferson Laboratory (Jlab)

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Cryogenic Systems

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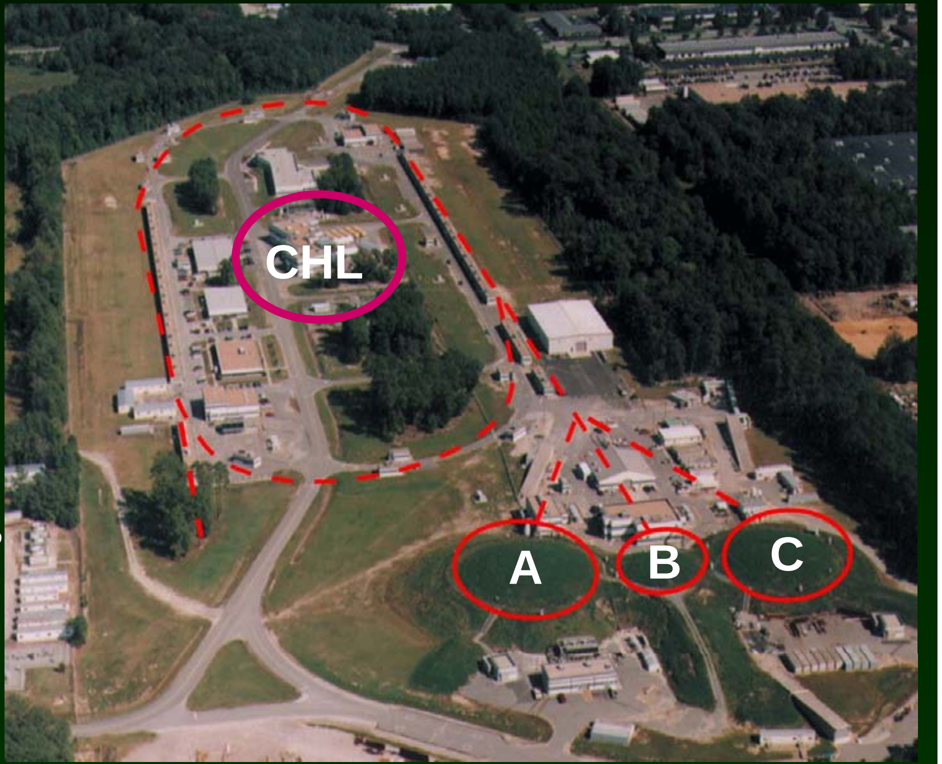
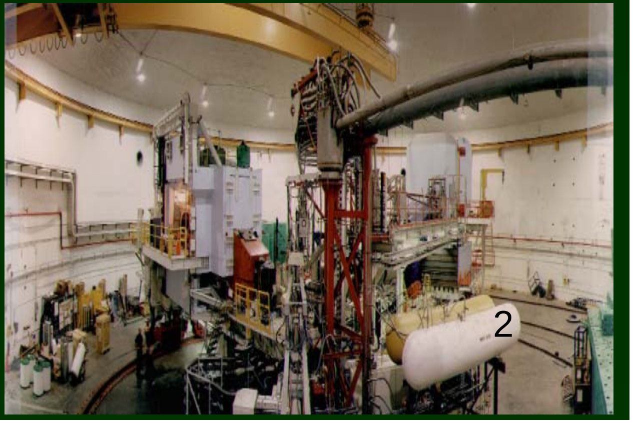
Jefferson Lab Today

2000 member international user community engaged in exploring quark-gluon structure of matter

Superconducting accelerator provides 100% duty factor beams of unprecedented quality, with energies up to 6 GeV

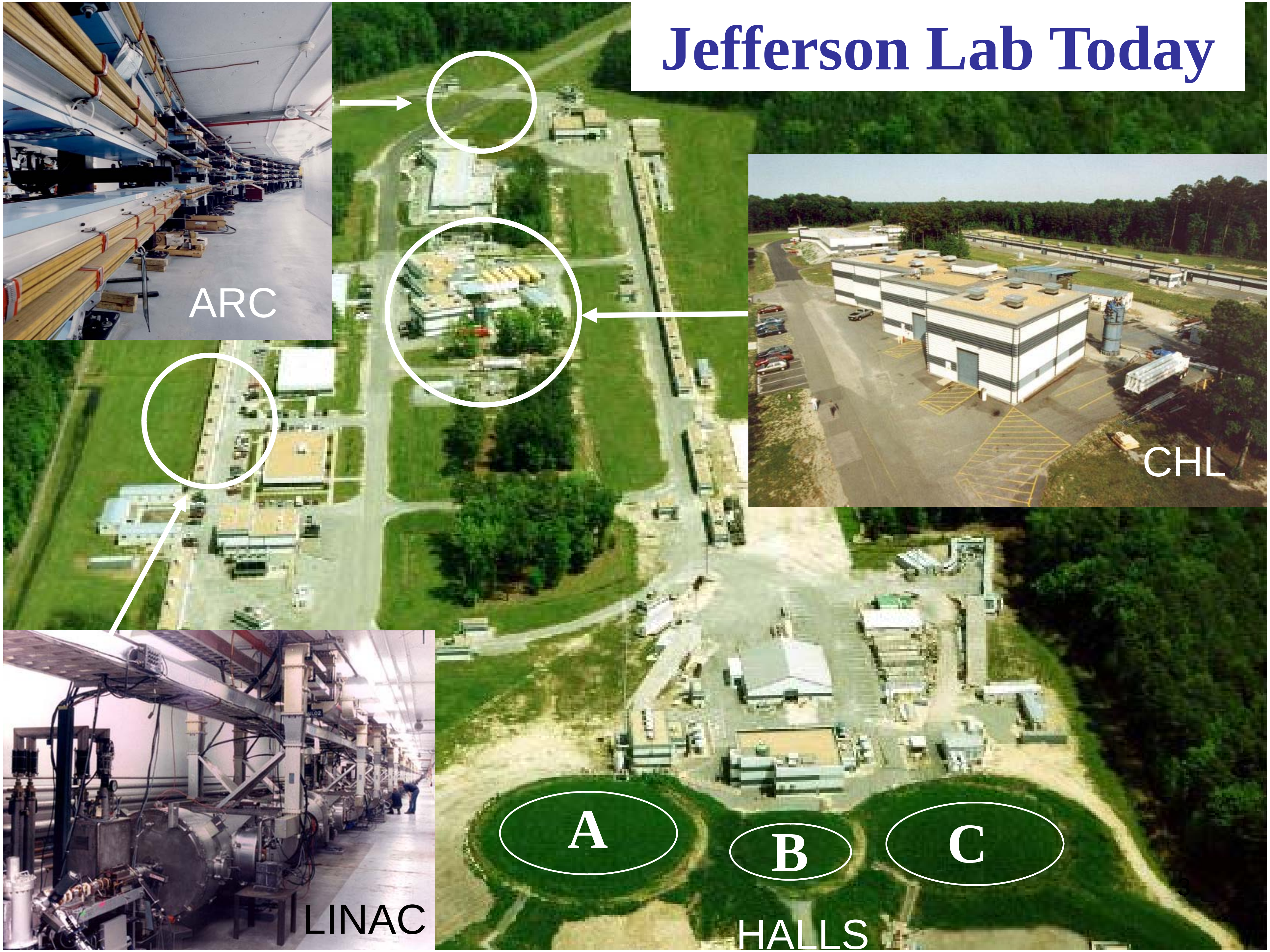


CEBAF's innovative design allows delivery of beam with unique properties to three experimental halls simultaneously

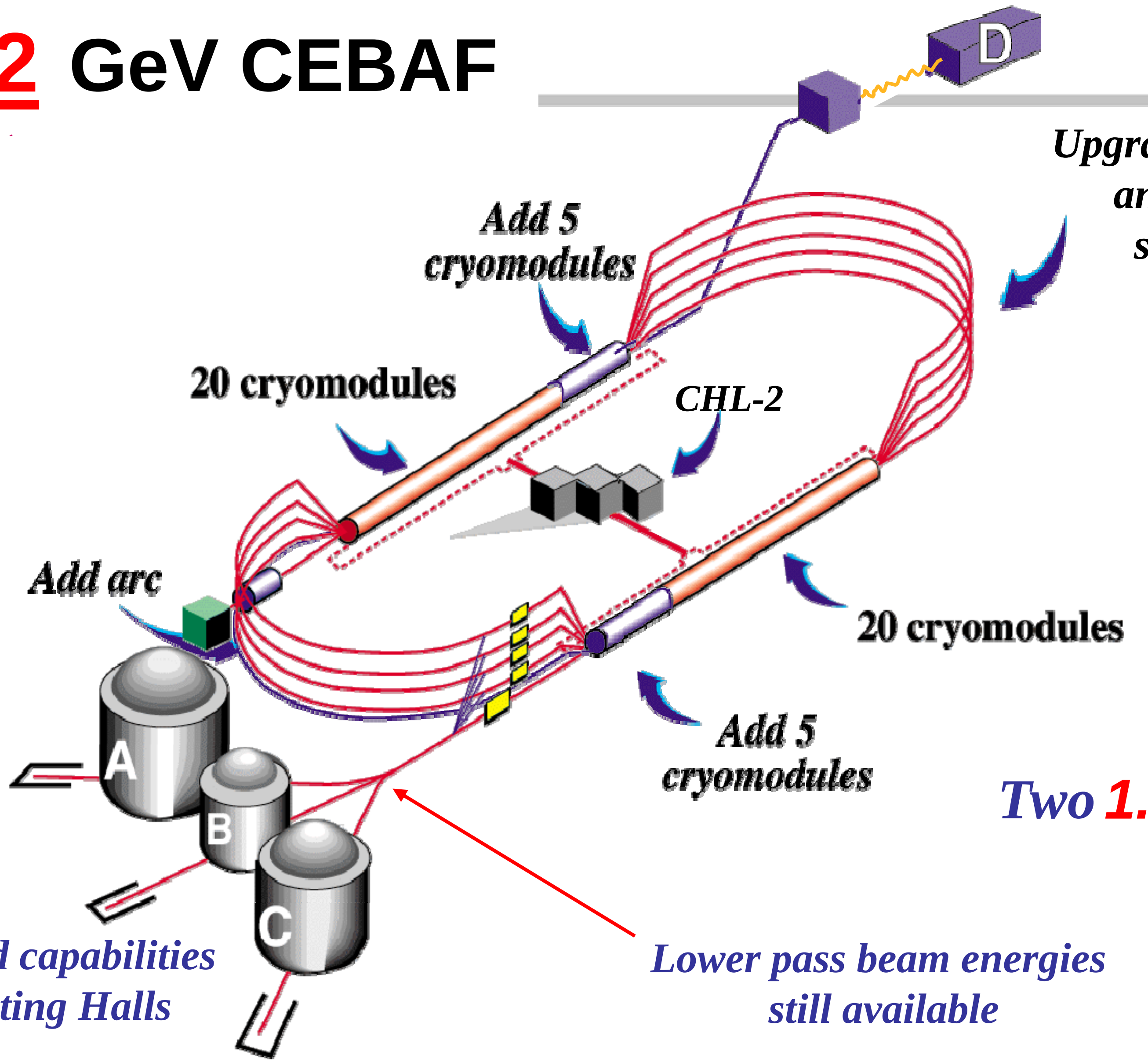


Each of the three halls offers complementary experimental capabilities and allows for large equipment installations to extend scientific reach

Jefferson Lab Today



12 GeV CEBAF



*Two **1.1** GV linacs*

Enhanced capabilities in existing Halls

Lower pass beam energies still available

Additional Loads of 12 GeV

- CEBAF Accelerator (Each new cryomodule)
  - Up to 300 W at 2.1K, Primary Load
  - Up to 300 W at 35 K, Shield Load

- Hall D (inclusive of cryogen distribution system)
  - 100 W at 4.5K refrigeration
  - 0.7 g/s of liquefaction (lead cooling)

CHL Max Capacity Current vs. New

- **Current 6 GeV (CHL #1)**
  – Load: 4.25 kW @ 2.1K, 11.65 kW @ 35K
  – Capacity: 4.6 kW @2.1K, 12 kW @ 35K
  – 10 g/s liquefaction

- **New 12 GeV (CHL #1 + new CHL#2)**
  – Load: 7.25 kW @ 2.1K, 14.65 kW @ 35K
  – Capacity: 9.2 kW @ 2.1K, 24 kW @ 35K
  – 25 g/s liquefaction

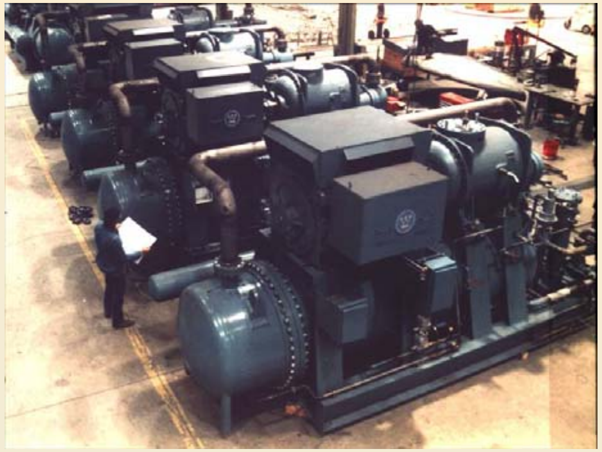
Loads/Capacities: CHL 6GeV vs.12GeV

Color key
6 GeV ops
12 GeV ops
Both

Unit Loads			6 GeV			12 GeV North Linac			12 GeV South Linac		
	2 K (W)	50 K (W)	#	2 K (W)	50 K (W)	#	2 K (W)	50 K (W)	#	2 K (W)	50 K (W)
Static loads											
Transfer Line	530	6360	1	530	7000	0.57	228	3990	0.43	302	3010
Original CM's	16	110	42.25	676	4648	21.25	340	2448	20	320	2200
12 GeV CM's	50	250				5	250	1250	5	250	1250
Dynamic loads											
Original CM's	72		42.25	3042		21.25	1530		20	1440	
12 GeV CM	250	50				5	1250	250	5	1250	250
Totals			42.25	4248	11648	25.25	3598	7938	29.25	3562	6710
Capacities (W)											
CHL#1 (W)				4600	12000		4600	12000			
% of Full Load				92%	97%		78%	66%			
CHL#2(W)										4600	12000
% of Full Load										77%	56%

Existing 6 GeV 4600W 2.1K CHL Helium Plant

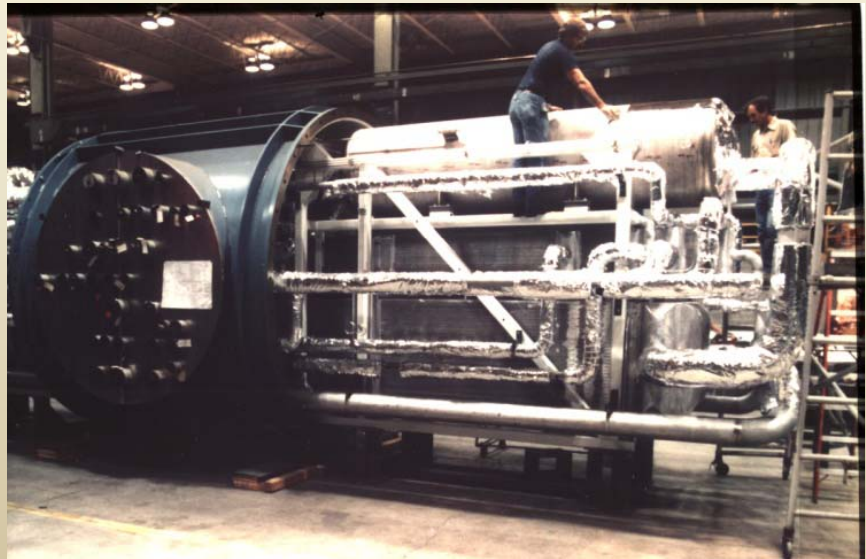
Helium Compressors



4K and 1st 2K Cold Box

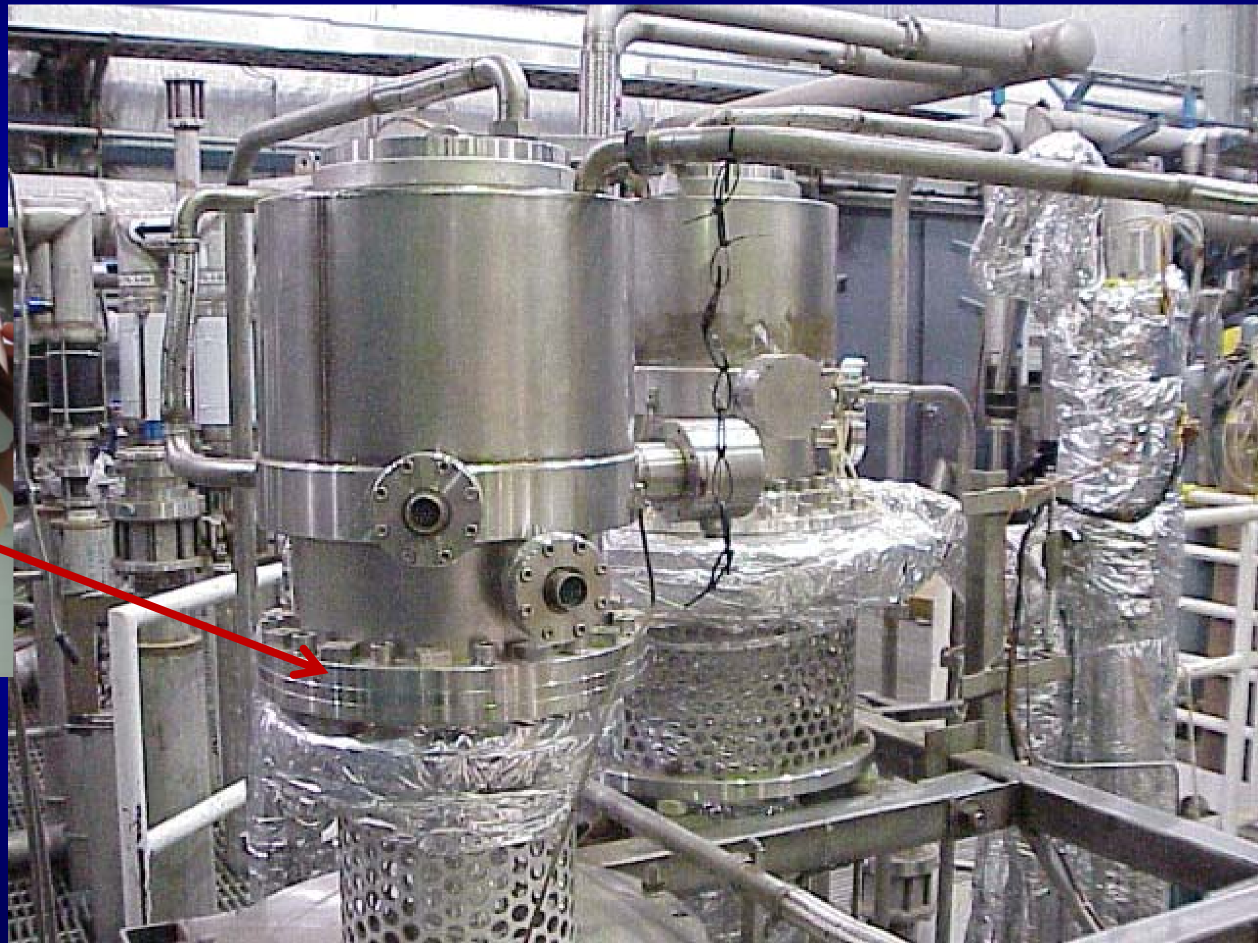
JLab 2nd 2K Cold Box

4K Cold Box Internals



2K Cold Box Internals

2K Cold Compressors

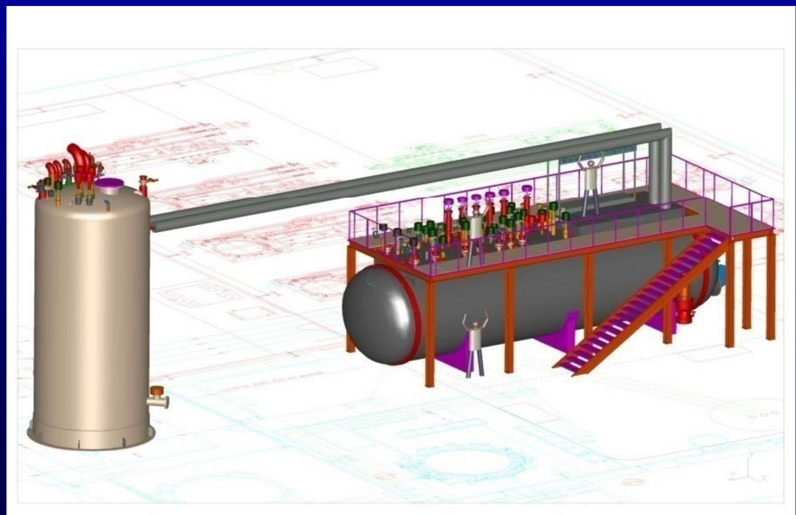


12 GeV “Split” 4.5K Cold Box Design

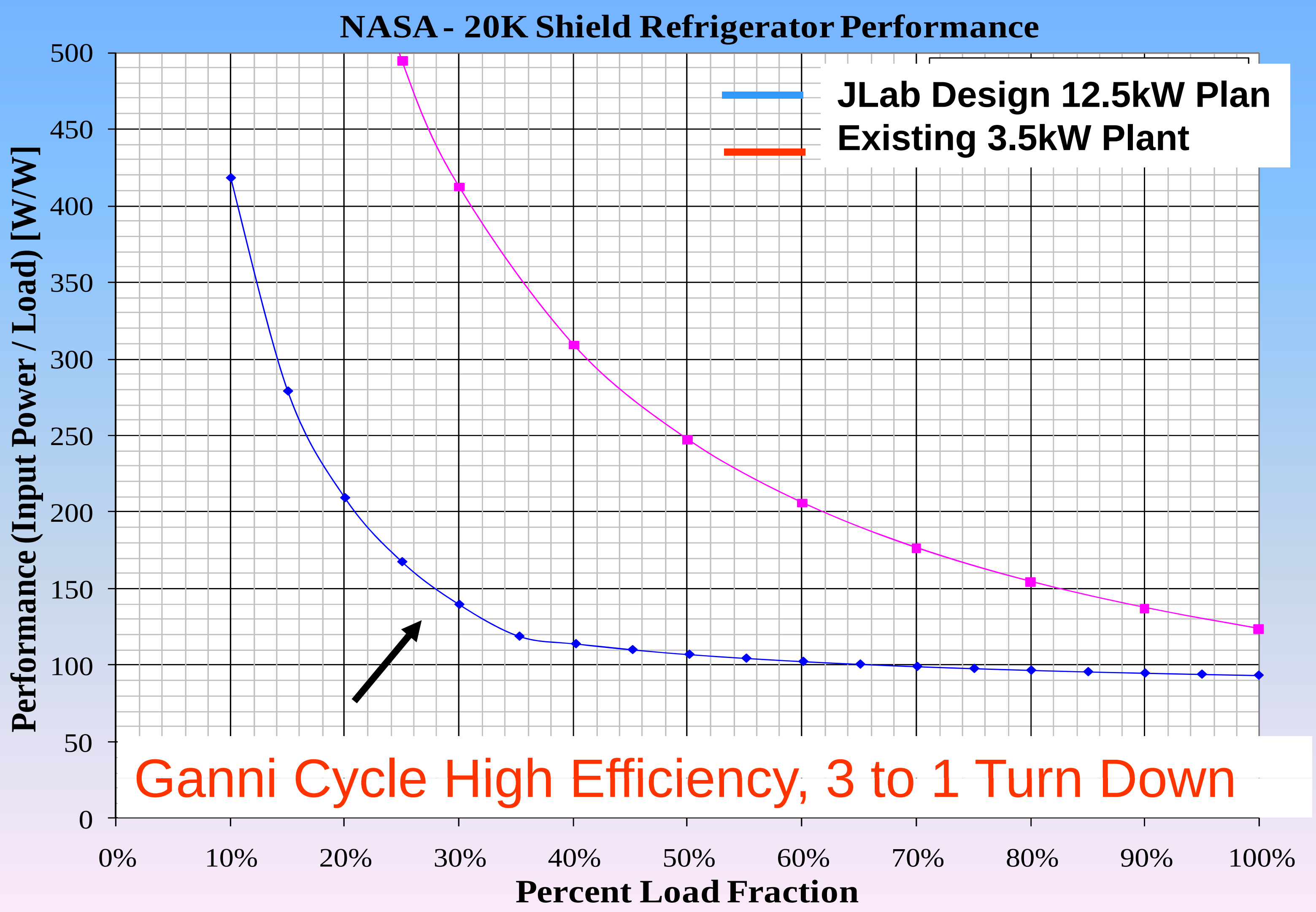
Uses JLab Ganni Helium Cycle In “Split Cold Box Design”

- Moves large upper temperature section (>80K) out-of-doors for smaller indoor system foot print and easier field construction for facility cost reduction, eliminates special building feature requirements such as large building access doors and cold box insulating vacuum floor pits, enables use of existing building without modifications

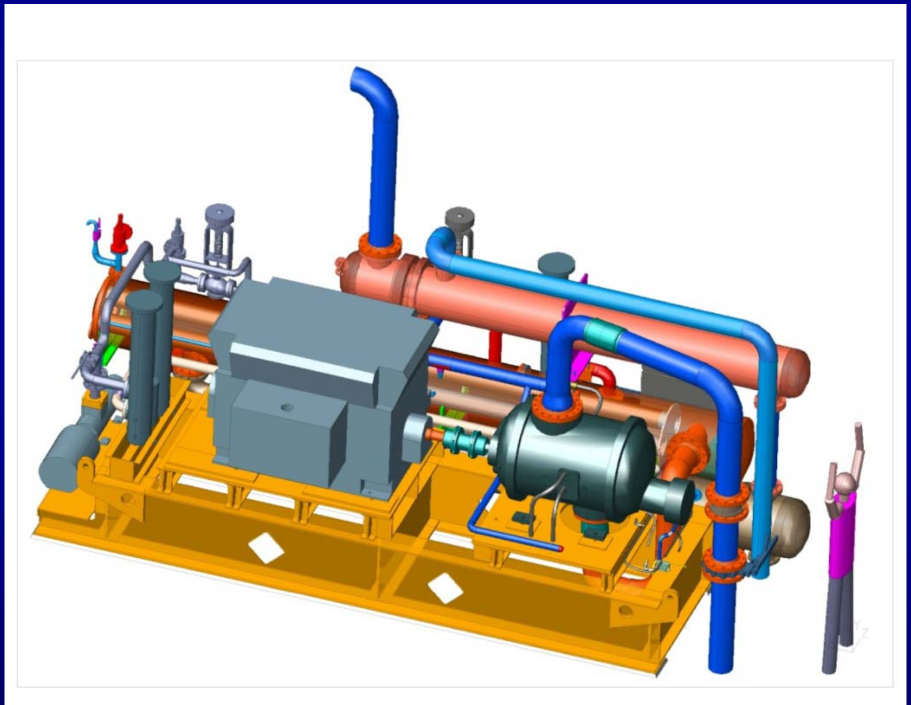
- Has lower temperature (<80K) section indoors which contains turbines, valves, etc. which require personnel access and controlled work environment



New Process Example
NASA-JSC "Ganni" Efficiency vs. Load
(Jlab/NASA JSC Collaboration)



12 GeV Compressor Design Model



Design Goals

•Improved Efficiency (highest current system losses)

•Development outlined in FY07 JLab S+T R&D Review Goals

•Lower Equipment Cost

•Solves current common reoccurring industrial design problems (ex: oil removal, maintenance requirements, etc.) using “lessons learned”

•Provides new design model using newly vendor developed internal oil injection system

12 GeV Refrigerator System Impacts

Uses the Jlab patent "Ganni Process Cycle" as baseline

- Same 4600W @ 2.1K CHL capacity as existing CHL-1 facility
- High system efficiency (28% Carnot) and stability for wide operating refrigeration operating domain
- 5.5 MW utility reduction to <4 MW power reduction based on vendor feedback
- Vendors unable to suggest lower cost system during RFI

12 GeV Refrigerator System Impacts

Uses Newly developed JLab Compressor R+D Design Model

- Design fully funded by NASA-JSC for James Webb Telescope test facility compressor development to correct operational problems experienced by JSC since late 1990s
- identical to JLab 12 GeV project compressor requirements saving 12 GeV project engineering or DOE development costs (~$200K)
- Curbs current rapidly rising carbon steel prices by substantially reducing compressor skid vessel sizing (Ex: 48” ➡ 24” diameter) and eliminating costly high pressure flange ratings (carbon steel costs up 52% since Jan 08)
- Uses JLab oil removal process technology to eliminate current industrial system oil carry over problem plaguing many current helium refrigeration systems
- Utilizes compressor built-in volume adjustment control and lower pressure loss to increase overall compressor skid efficiency to 55%

Key 12 GeV Cost Advantages

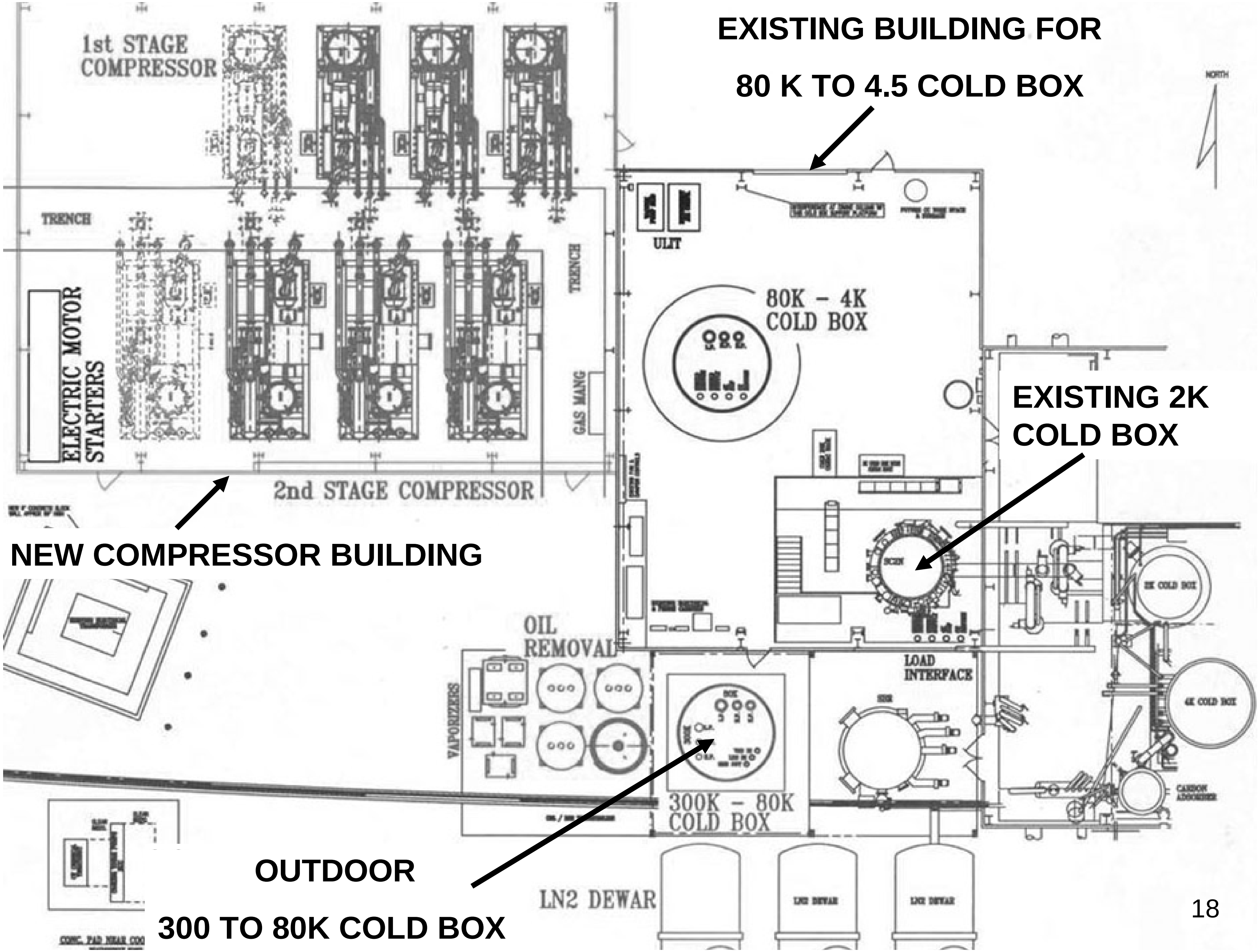
- Half of needed CHL buildings exist
- Original Linac transfer lines can support twice the flow
- Linac liquid inventory in linacs changes only 5%
- The 2K cold compressor system already installed
- 480V Power source for new CHL building exists
- Some shared equipment design cost with NASA

Existing 6 GeV CHL Systems

- ✓ Gaseous Helium Storage
- ✓ LN_2 Storage Dewars (twin 80,000 liter)
- ✓ Cold Compressor Sets (twin 245 g/s)
- ✓ Helium Gas Purification and Contamination Monitors
- ✓ Guard Vacuum Subsystem (2.1K operations)
- ✓ Building for lower 80-4.5 K Cold Box
- ✓ Outdoor Foundation for upper 300-80 K Cold Box
- ✓ Linac Cryogen Distribution Piping (ok for double flow)

New Equipment for CHL#2

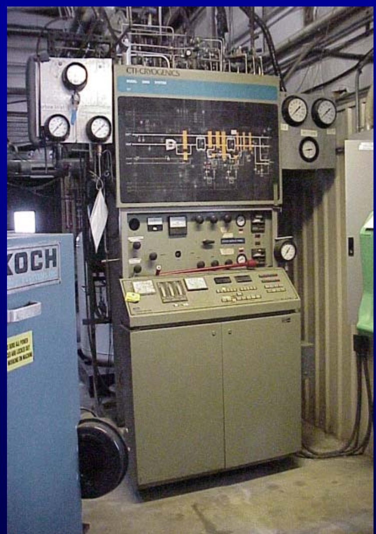
- 4.5 K cold box and warm helium compressors
  - Two sectional 4.5K cold box, (300-80K, 80K-4.5K)
  - Design baseline is JLab's Ganni Helium Process Cycle
  - Supports 4600 W @ 2.1 K and 12 kW at 35 K
- Compressor oil removal system
- Computer distributive control system
- Cooling Water System (twin 15,200 l/min)
- Electrical Power (twin 5 MW, 4160V)
- Helium Dewar, 10,000 l
- 4800 ft^2 compressor building


EXISTING BUILDING FOR
80 K TO 4.5 COLD BOX
EXISTING 2K
COLD BOX
NEW COMPRESSOR BUILDING
OUTDOOR
300 TO 80K COLD BOX
1st STAGE
COMPRESSOR
TRENCH
ELECTRIC MOTOR
STARTERS
2nd STAGE COMPRESSOR
GAS MANG
ULIT
80K - 4K
COLD BOX
OIL
REMOVAL
VAPORIZERS
LOAD
INTERFACE
300K - 80K
COLD BOX
LN2 DEWAR
2K COLD BOX
4K COLD BOX
CARBON
ADSORBER
NORTH

Hall D Rendering

Hall D Refrigerator Equipment "On Hand"

- ✓Two CTI Cryogenics Helium RS Compressors
- ✓CTI M2800 200W 4.5 K Helium Refrigerator
- ✓LHe Subcooler Dewar
- ✓Motor Starters, 480V



Hall D Cryogenic Equipment Requirements

- Gas Management Valve Control Rack
- LN2 storage, 10,000 liter dewar
- One 4000 cf Helium Gas Storage Vessel
- Integrated Refrigerator Computer Controls
- Instrument Air System, 15 scfm
- Purification Loop Piping to the CHL via N. Linac
- 640 ft^2 building
- Compressor/Turbine Cooling Water
- 480V, 200 kW compressor power

12 GeV Cryogenic Schedule

✓ October 2006 – October 2008	CD-2, Project Engineering and Design Status
✓ October 2008	CD-3, Project Construction Status
January-April 2009 ★	CHL#2 Major Component Purchase
October 2009	CHL#2 Building Construction Complete
October 2010	CHL#2 Utilities Construction Complete
February 2011	CHL#2 Major Equip Delivery/Installation
	Hall D Refrigerator Building BOD
May-November 2011	Hall D Refrigerator Installation
October 2011-April 2012	CHL#2 Commissioning
February 2012	Hall D Refrigerator Commissioning

Current Cryogenic Status

- Construction Phase Approved (CD-3)
- Currently evaluating 4.5K Refrigerator Bid Proposals
- CHL Civil Design ~100% Complete and Bids Received
- Hall D Civil Design ~100% Complete
- Major Cryogenic Specifications Developed
- System P&IDs and system drawings generated (~120)
- Detailed Process Cycle Analysis Complete
- Equipment Cost Baseline Established
- Equipment Installation Design FY09
- Have completed 8 Major Reviews Successfully
- Ahead of Schedule and Budget

Thank You for Your Kind Attention

May We Answer Your Questions ?

Compressor Characteristics

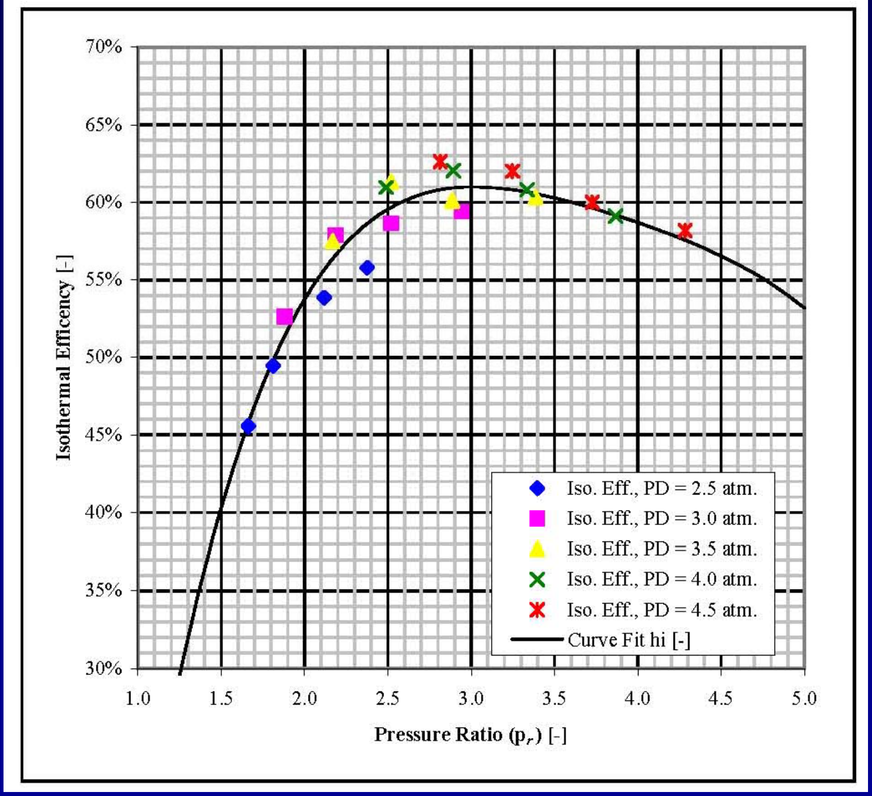


FIGURE 1.3 BRV=2.2 1st Stage

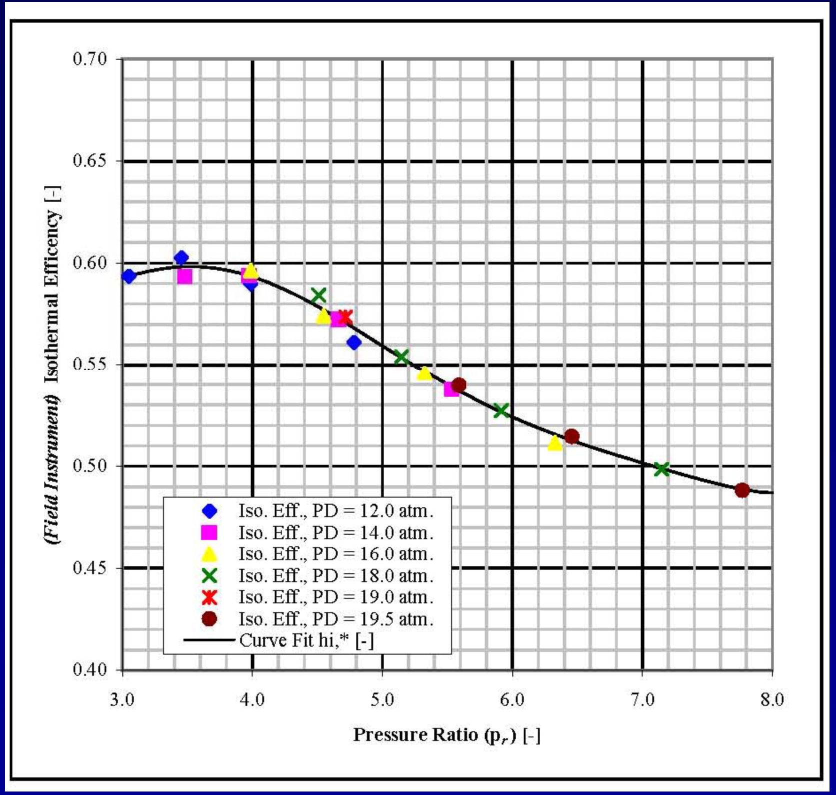
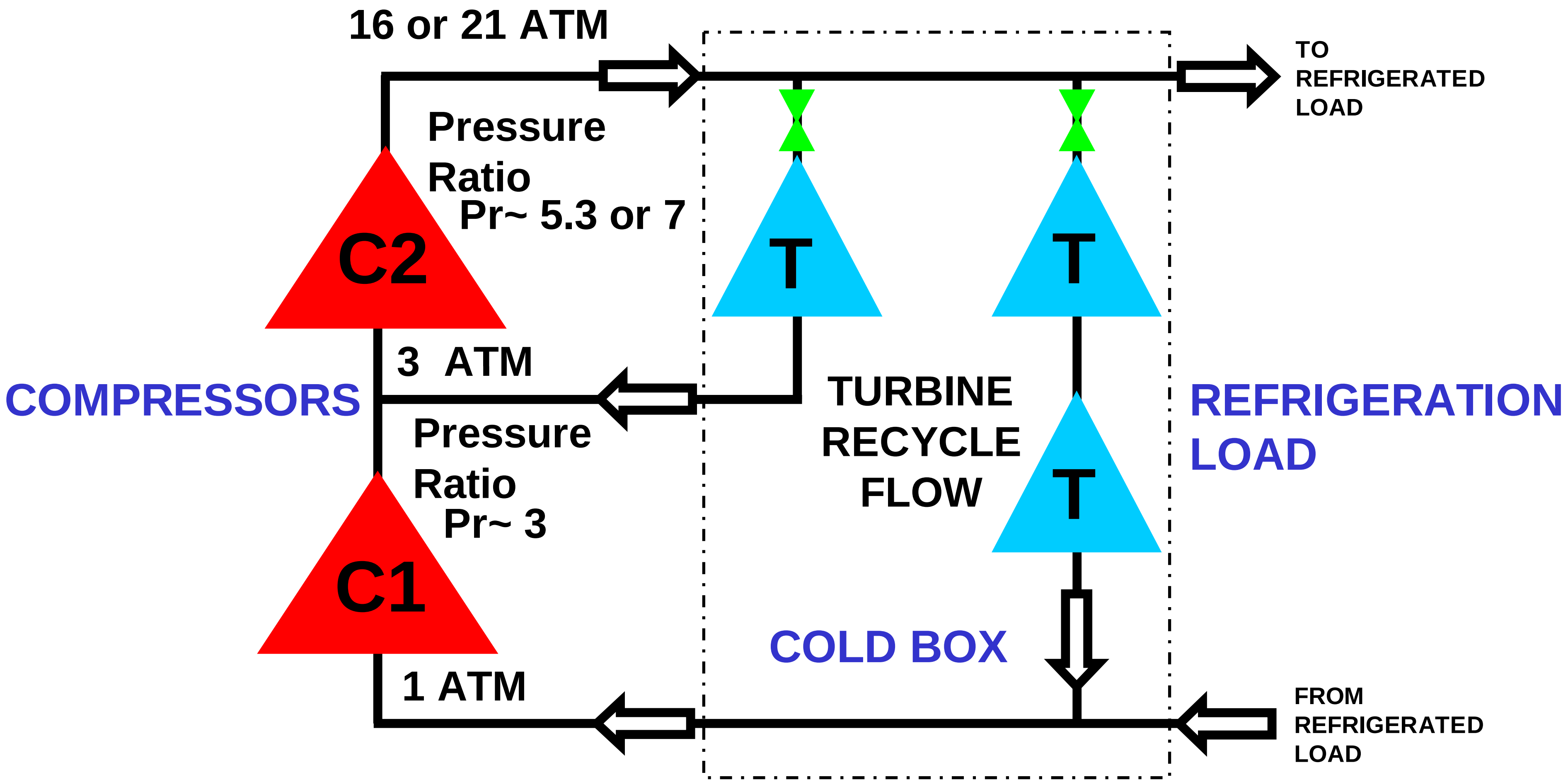


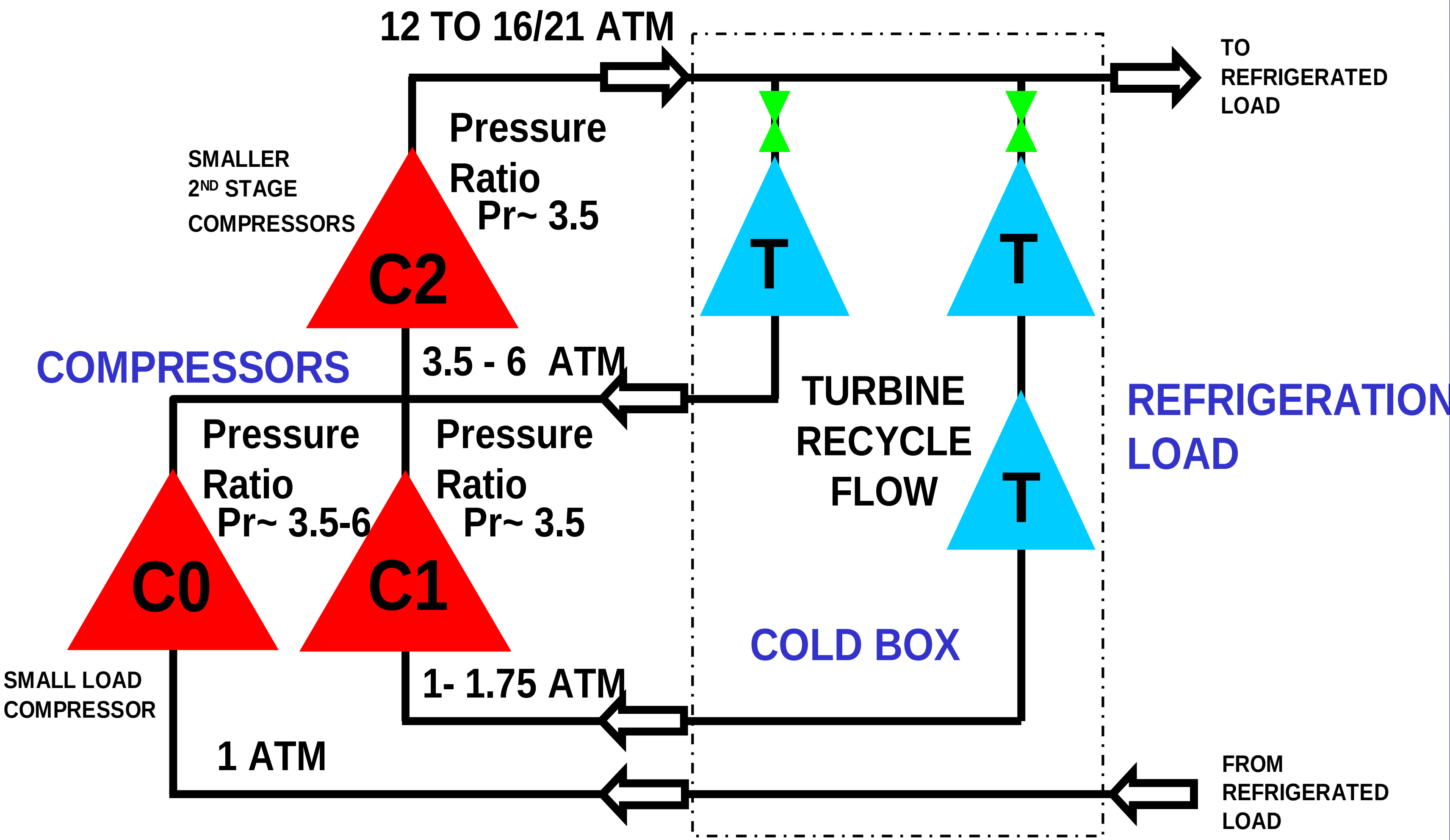
FIGURE 1.4 BRV=2.6 2nd Stage

Standard Cycle



STANDARD INDUSTRIAL HELIUM REFRIGERATION SYSTEM

Ganni Cycle



GANNI CYCLE (FLOATING PRESSURE) HELIUM REFRIGERATION SYSTEM