Accelerator Division
All Hands Meeting
April 17, 2009

Andrew Hutton

Outline

- A big **thank you**
- Budget stuff
- My talk to the JSA Science Board
  - Accelerator R&D Overview

Geraldine

Overview

- Geraldine was diagnosed with Hodgins Disease in October 2007
- The initial 6 months chemo regime (ABVD) cures five patients out of six
  - Geraldine was the other one
- Three months of targeted radiation therapy also failed
- Solution was tandem (yes, two) stem-cell transplants
  - Heavy chemo #1
  - Extract Geraldine's own stem cells
  - Different heavy chemo #2
  - Re-inject stem cells
  - Wait six weeks to ~recover
  - Repeat with third kind of heavy chemo #3
  - Re-inject stem cells


EMERGENCY EXIT PLAN
12/9/08
Alaris Pump
Alaris Pump

What Did I Learn

- I filed for FEMLA leave
  - Everyone filled in for me
  - More support than I would have ever believed
  - You can rely on your JLab family
- Everyone should arrange to accompany a friend to chemo
  - You will do them a service
  - You will do yourself an even greater service
  - It resets your priorities
- Realize that this can happen to anyone – even me
  - I should act like every day might be my last
  - Don't go to bed at night without resolving arguments and telling your loved ones that you love them

Thank You

- Geraldine and I want to thank all of you who have helped us over the last 18 months
- Many of you increased your workloads to fill in for me
- Many of you sent gifts and get well cards
- Geraldine is here today, and you had a part in it

THANK YOU

Geraldine and Viviane

Budget Stuff

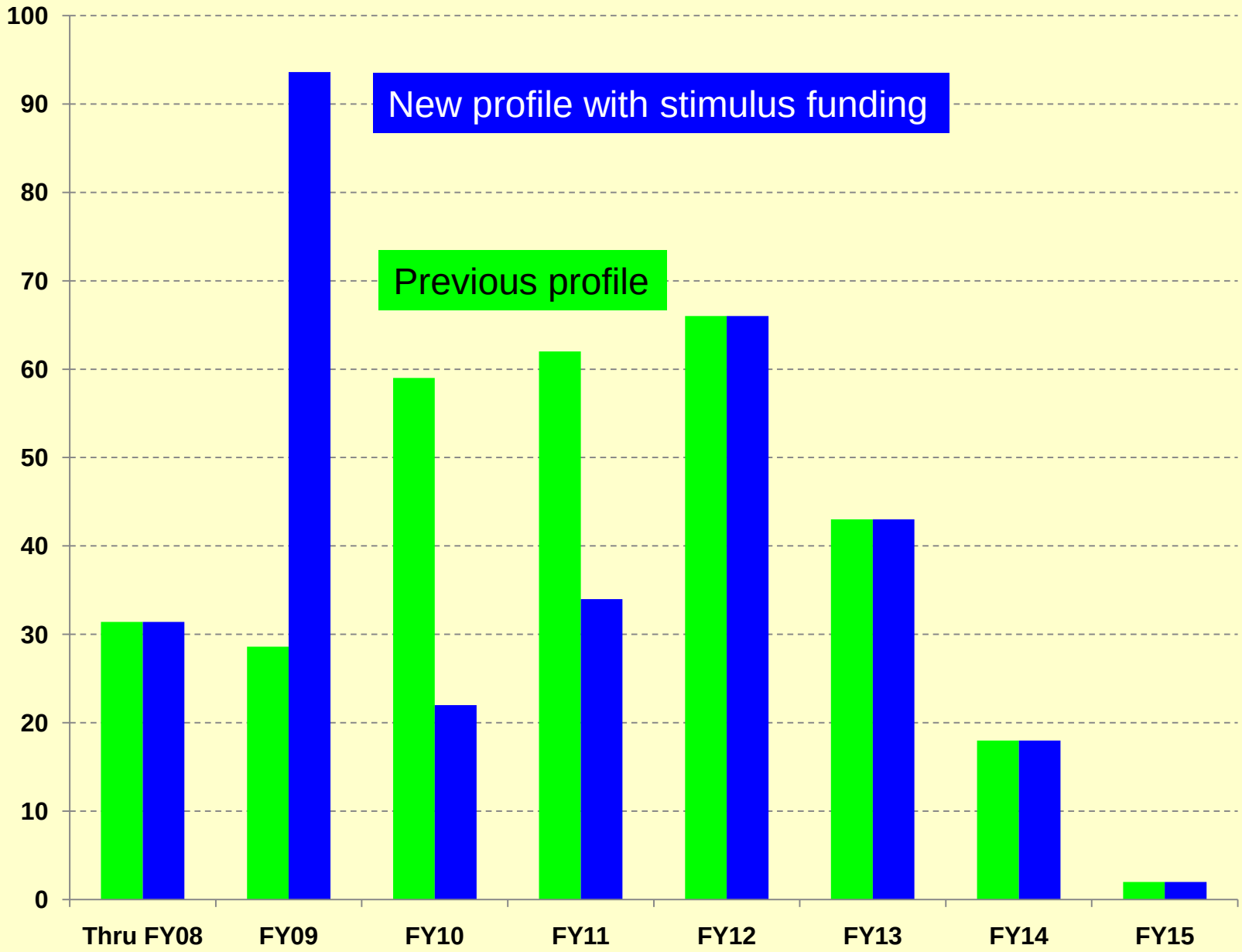
What Did President's Budget Get Us?

- Labor budget increase to cover promotions and salary increases (~$550K)
- Increase to cover Injector Upgrade (higher voltage gun and Wien filter) ($400K)
- Running weeks changed from 26 to 34 weeks
  - The FY'09 schedule with the run extension to 3/15
  - A lengthened March/April downtime for cryomodule commissioning
  - A spring run from 4/20 (accelerator on) to 6/14 (accelerator off)
  - An August 17th startup for physics
- Power budget increase to cover 8 weeks of additional running and rate changes (~$500K)
- Use any remaining funds to cover spares for increased running weeks – requesting ($110K)

What Additional Funding Have We Received?

- **$65,000,000 advance funding for the 12 GeV CEBAF Upgrade Project**
- **$10,000,000 for the following General Plant Projects (GPP) projects:**
    1. **Experimental Staging Facility**
    2. **Expand General Purpose Building**
    3. **End Station Refrigerator Building and Utilities**
    4. **Test Lab Serviced Transformer Upgrade**
    5. **Roads and Parking Improvements (partial)**
- **$2,760,000 in Accelerator Improvement Project (AIP) funding for the 11 GeV Separator for the JLab Upgrade**
- **$4,965,000 for the acquisition and operation of dedicated QCD computer hardware**

12 GeV Funding Profile

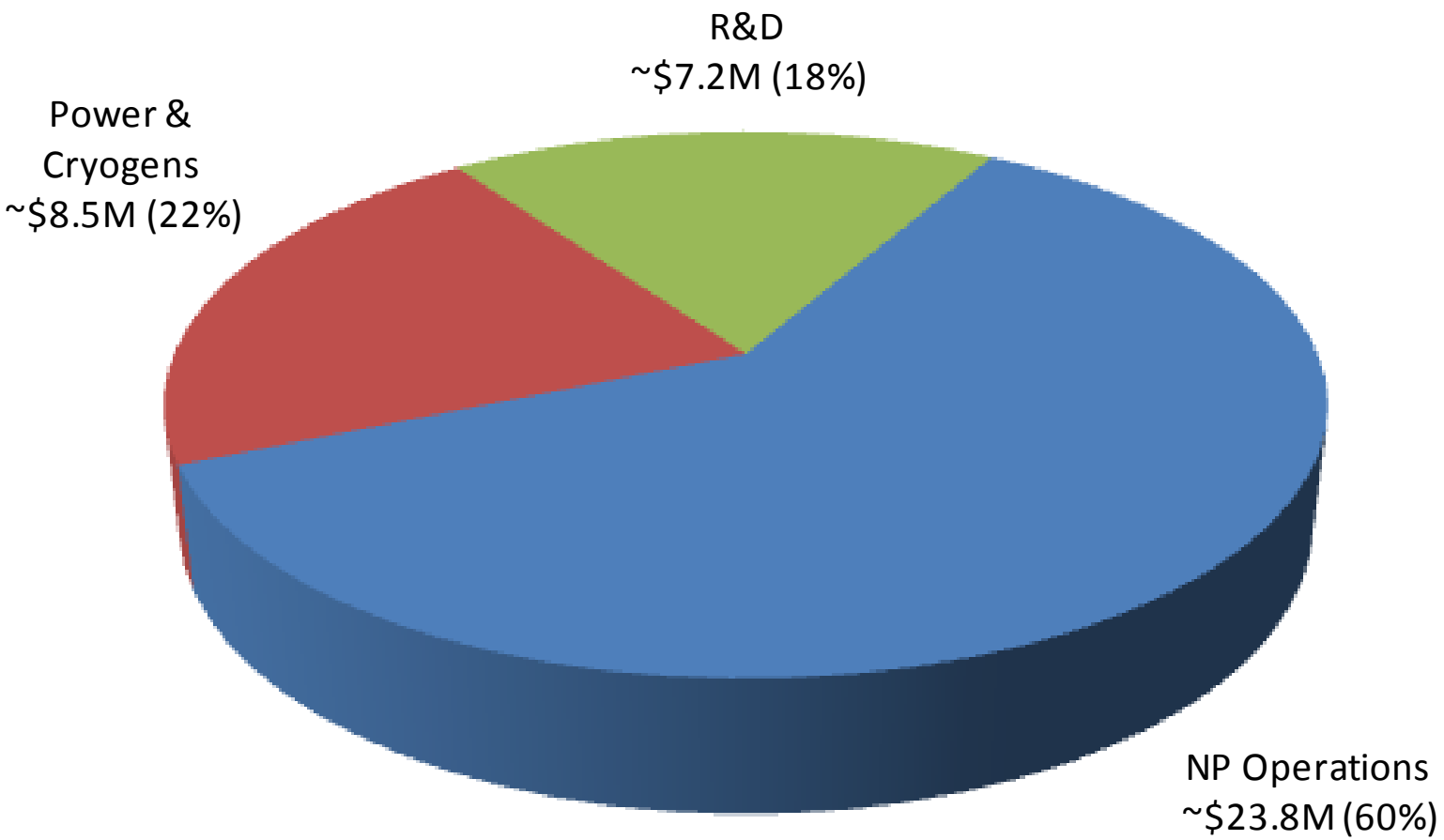


Is That It? NO!

- HEP
  - ILC – expect $250k increase ($450k more than we received to date)
  - Rumors of $900k more for Test Lab equipment
- NP
  - Submitted requests for stimulus funds
- NIH
  - JLab has submitted requests for FEL UV beamline and laboratory equipment
- Homeland Security
  - Expect $1.8M to pay for 1 weeks running in Jan 10
    - 800 MeV, <1μA to Hall B
    - Split between Physics and Accelerator

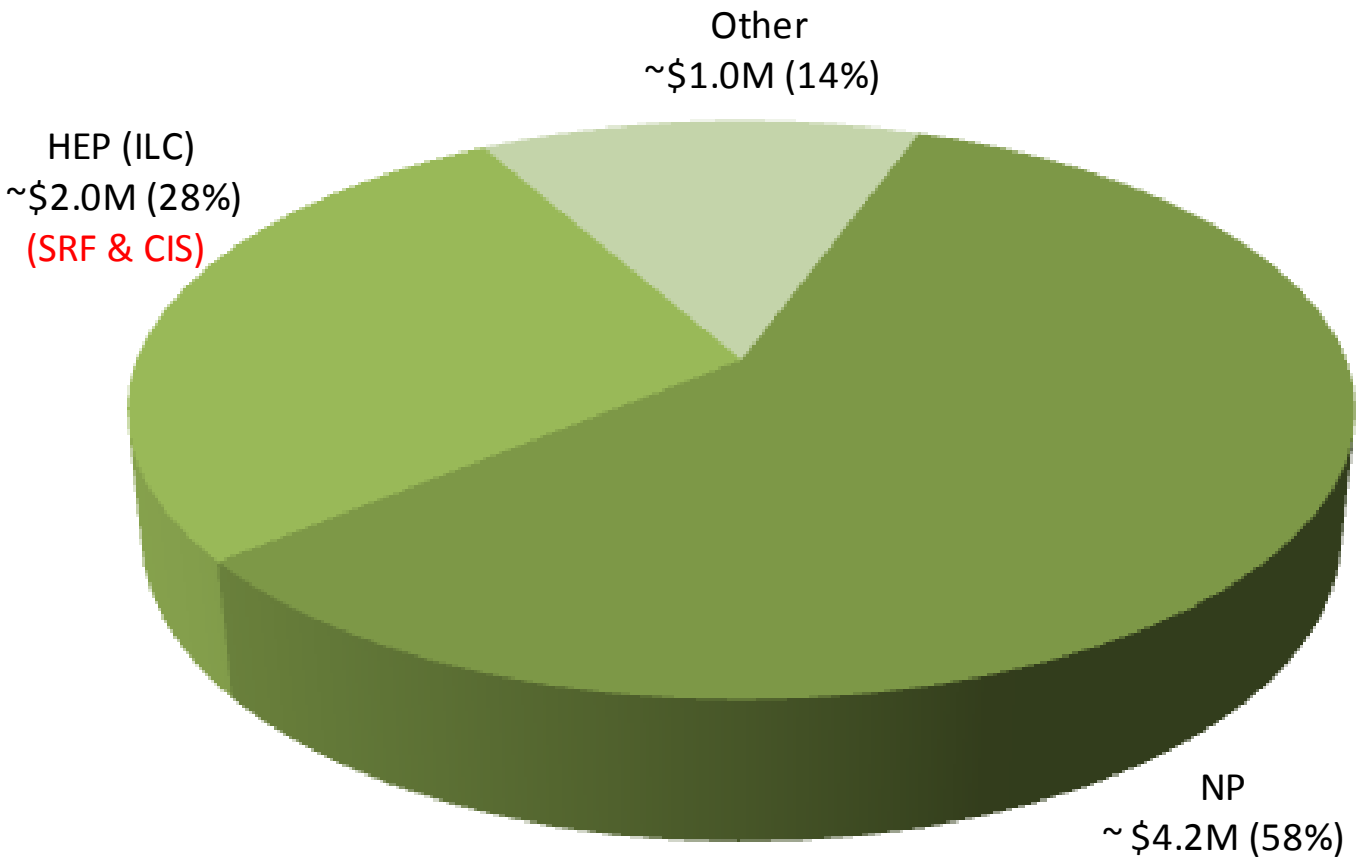
Accelerator Budget with Overhead

Without PB additions



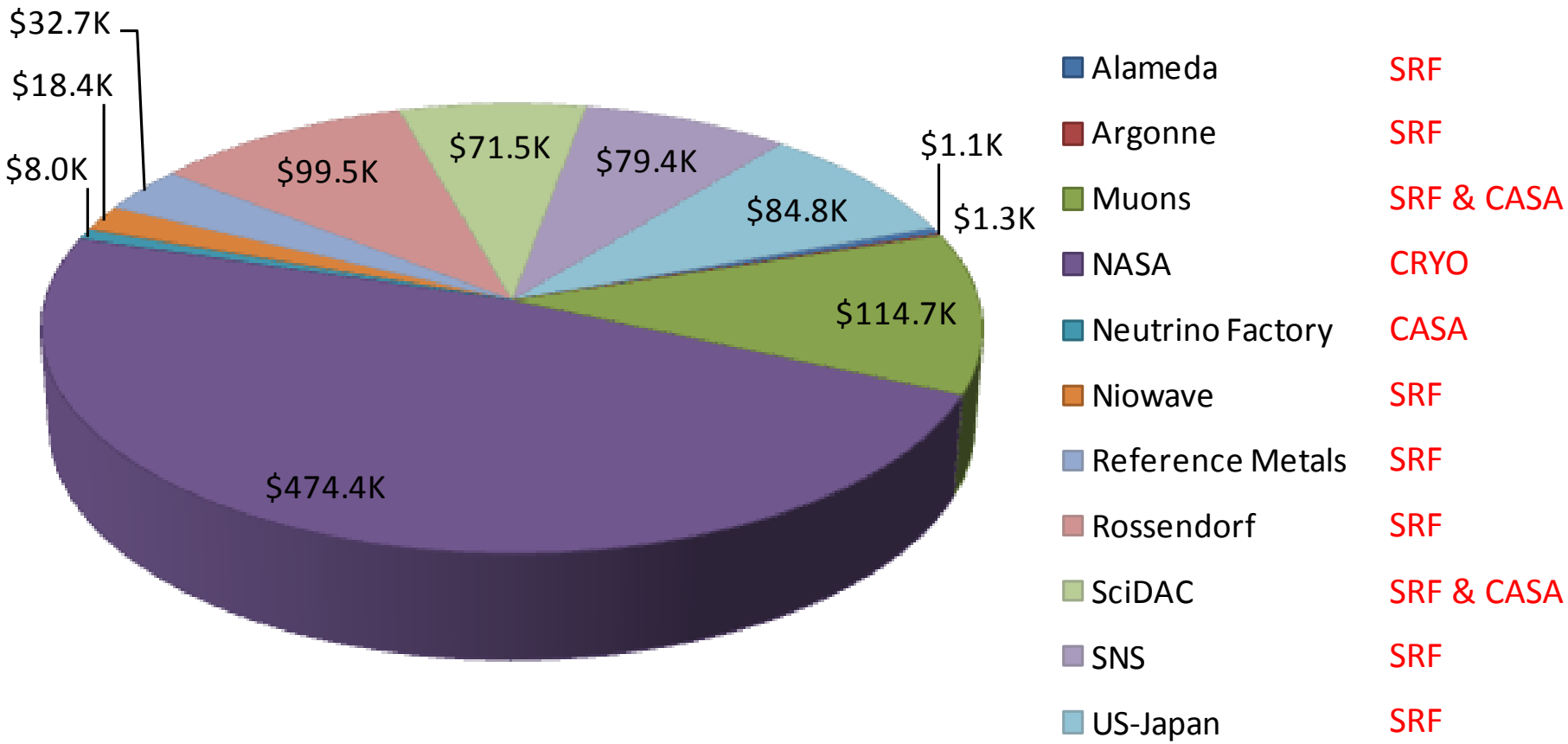
Accelerator R&D Budget with Overhead

Without PB additions



Accelerator R&D Other Budget with Overhead

Without PB additions



Accelerator R&D Overview

Andrew Hutton
Associate Director for Accelerators

Presentation to JSA Science Board
April 10, 2009

Outline

- Long-Term Accelerator Facility Vision
- R&D Portfolio
- External Partnerships
- Education

Long-Term Accelerator Facility Vision

Future Accelerator Options at JLab

- The top choice for a future facility at JLab is ELIC, an ELectron Ion Collider
  - Provides a long-term future for Nuclear Physics at JLab
  - Recently, a staged approach was worked out (MEIC)
- Positron option for CEBAF
  - Working with IAC (Idaho Accelerator Center), Université Joseph Fornier, Grenoble, France, and Old Dominion University (ODU) to develop the technology for a positron pre-burner for CEBAF
- 4th Generation Light Source
  - Good match to our technology
  - JLab plans based on development of the FEL
  - Hoping for BES R&D investment
    - Aiming to be the "recipient of choice" by initiating relevant R&D on other money so we have a head start

Future Accelerator Options Set R&D Direction

- All of these options build on our core competencies

R&D aims to further improve our core competencies and to be applicable to most options

- Today's presentation will describe the R&D carried out by the Accelerator Division in support of these long-term accelerator options
  - I will not talk to slides with black corner
    - Included to give an idea of the breadth of the R&D

R&D Portfolio

R&D Strengths

- Accelerator Division contains the core competencies in accelerator science and technology
  - SRF (SRF Institute) led by Bob Rimmer
  - Cryogenics R&D led by Dana Arenius and Rao Ganni
    - Matrixed from Engineering
  - Center for Injectors and Sources led by Matt Poelker
  - Accelerator Physics (CASA) led by Geoff Krafft
- The FEL Division is also tightly coupled for photon science
- These core competencies define JLab accelerator science

High current, CW, superconducting, multi-pass linacs

Accelerator Division R&D Goals

- Our goal is World Leadership in all our core competencies
  - SRF with particular focus on CW applications
  - High-efficiency Cryogenics
  - Electron Injectors (high current, CW, polarized and unpolarized)
  - Accelerator Physics (special focus on ELIC and Energy Recovery Linacs)

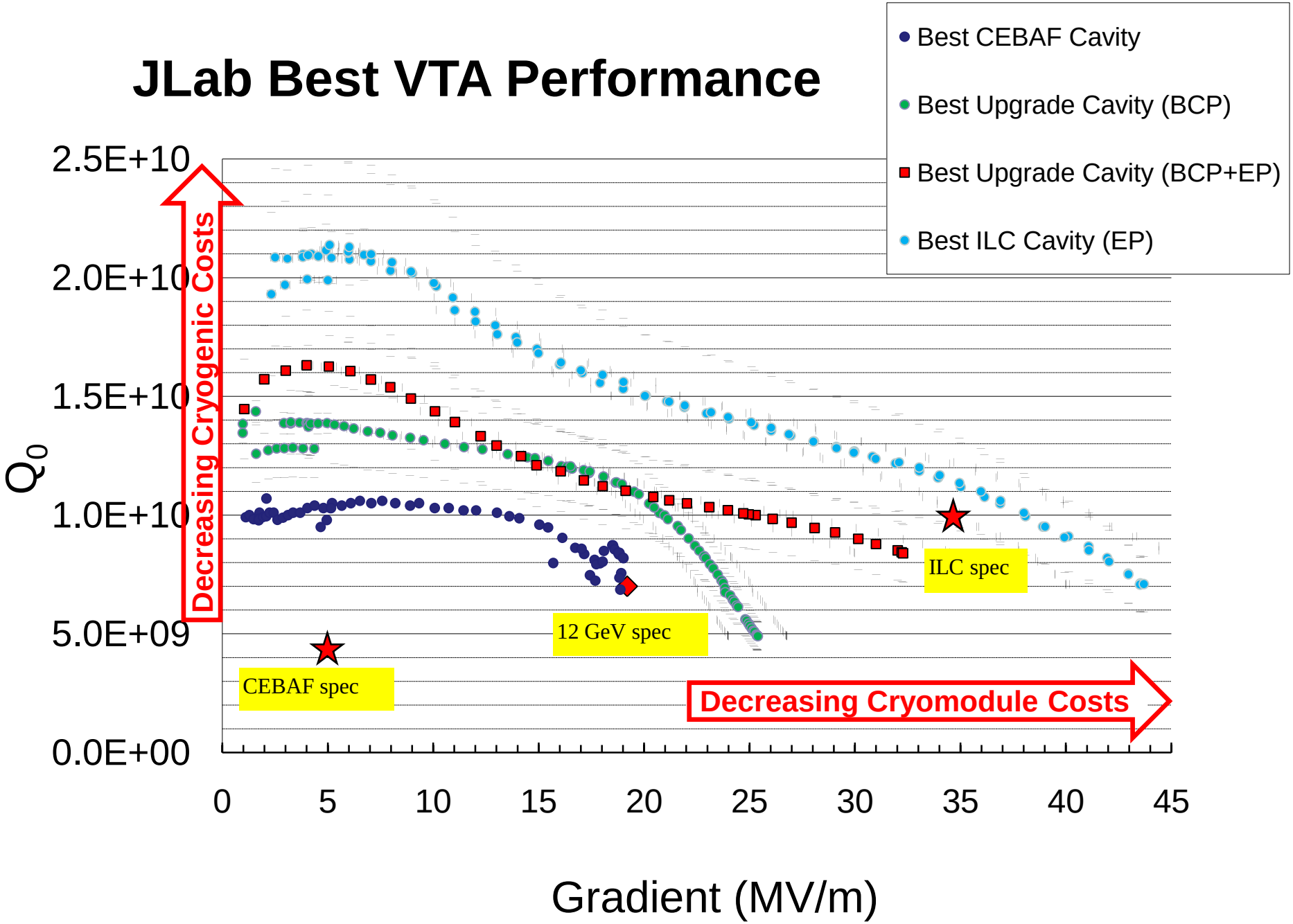
- Goals have been established for each R&D area which support the Accelerator Division Goals
  - Aiming for total alignment of the different R&D areas
    - Not there yet!

SRF Institute

- The SRF Institute has fabricated and/or processed a wider variety of multi-cell SRF cavities than anyone else
- 87 cavities fabricated / 634 multi-cell cavities processed
  - 25 different cavity types processed, including:
    - 9 different frequencies
    - 6 different beta values
    - Both CW and pulsed
- In addition a large number of single cell test cavities have been fabricated and/or processed
  - So many, we do not even have an exact count!
- 2945 cavity tests in VTA (Vertical Test Area)
  - Nearest competitor is DESY ~800!

Project	# of Cavities built @ Jlab	# of Cavities processed / tested	Frequency (MHz)	Beta	# of Cells	Duty Factor
CEBAF (OC cell shape)	20	358	1497	1	5	CW
CEBAF (OC) - C50 rework		94	1497	1	5	CW
CEBAF Upgrade Style (OC)	8	8	1497	1	7	CW
CEBAF Upgrade Style (LL)	5	5	1497	1	7	CW
CEBAF Upgrade Style (HG)	9	11	1497	1	7	CW
C100 - (LL)	2	2	1497	1	7	CW
FEL IR DEMO (OC)	10	10	1497	1	5	CW
FEL 10 kW Upgrade (OC)	8	8	1497	1	7	CW
FEL HCCM (HC)	3	3	1497	1	5	CW
FEL HCCM (HC)	1		750	1	5	CW
AES HC Inj		3	750	1	1	CW
AES HC Inj		1	1500	1	1	CW
APT	2	2	700	0.64	3	CW
APT		3	700	0.64	5	CW
SNS	4	44	805	0.61	6	Pulsed
SNS	1	52	805	0.81	6	Pulsed
RIA	2	2	805	0.47	6	Pulsed
INFN Legnaro - seamless		1	1500	1	5	CW
INFN Milan - TRASCO		1	703	0.5	5	CW
DESY - seamless		3	1300	1	2	CW
KEK	1	1	1300	1	10	Pulsed
ILC-like - superstructure	1	1	1497	1	10	Pulsed
BNL		1	704	1	5	CW
FLASH - FNAL/DESY	5		3900	1	9	Pulsed
ILC - (TESLA)		14	1300	1	9	Pulsed
ILC - (LL)	1	1	1300	1	7	Pulsed
ILC - (Japan LL)		1	1300	1	9	Pulsed
ILC - (TESLA)	4	4	1300	1	9	Pulsed
Total	**87**	**634**				

JLab Best VTA Performance



T= 2 K

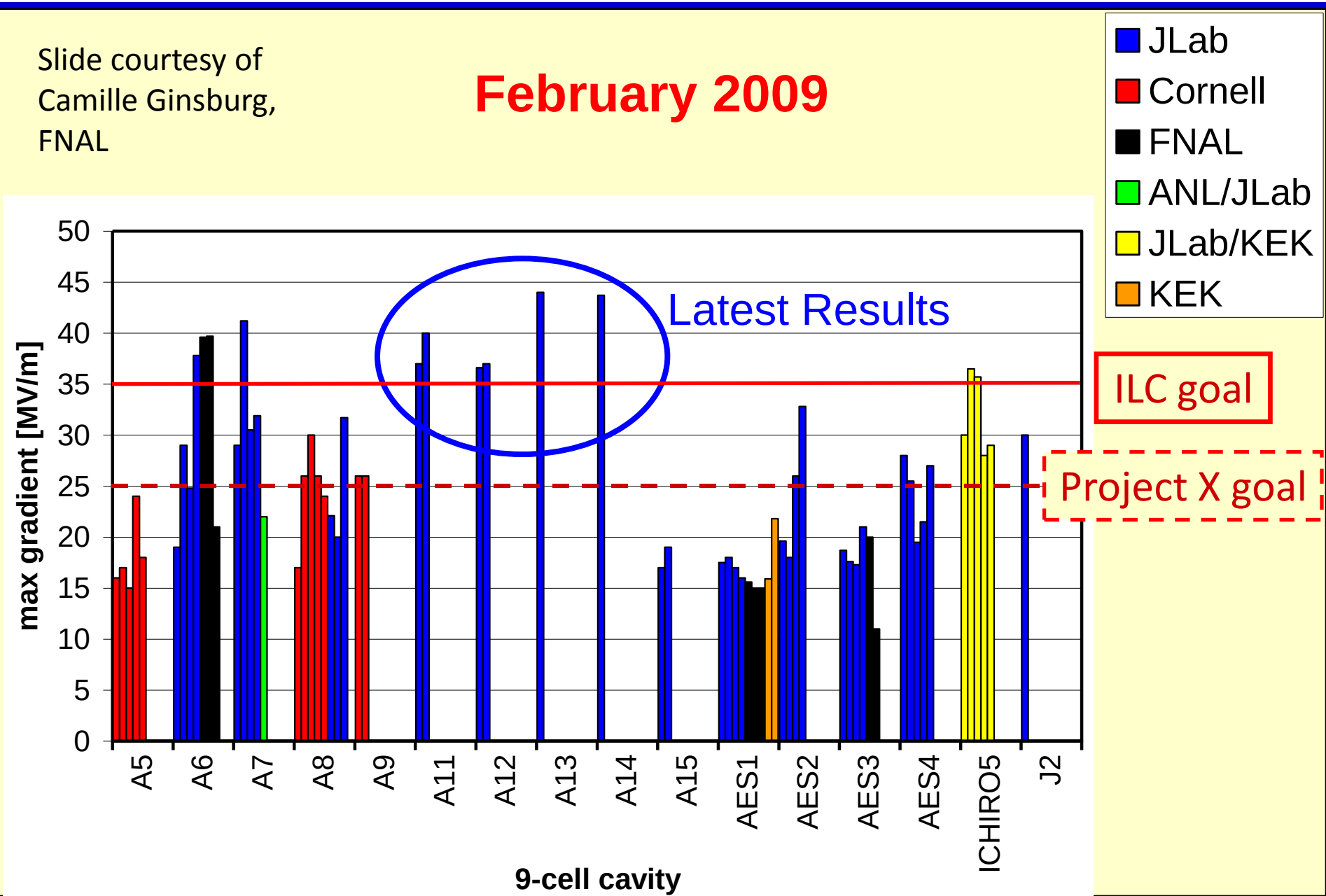
Increase gradient

- Challenges are to push gradient to fundamental material limits, narrow the spread in performance and eliminate early failures due to material or fabrication defects or contamination
- ILC high gradient program pushes this performance
  - JLab provides most cavity data for the Americas region
    - Improved cleaning and assembly practices
    - Electro-polishing process optimization
    - Developing next generation processing equipment
- Aim is to improve process yield through understanding
  - Quench fault location via temperature mapping
  - High-resolution optical inspection

Summary of 9-cell Vertical Tests in U.S.

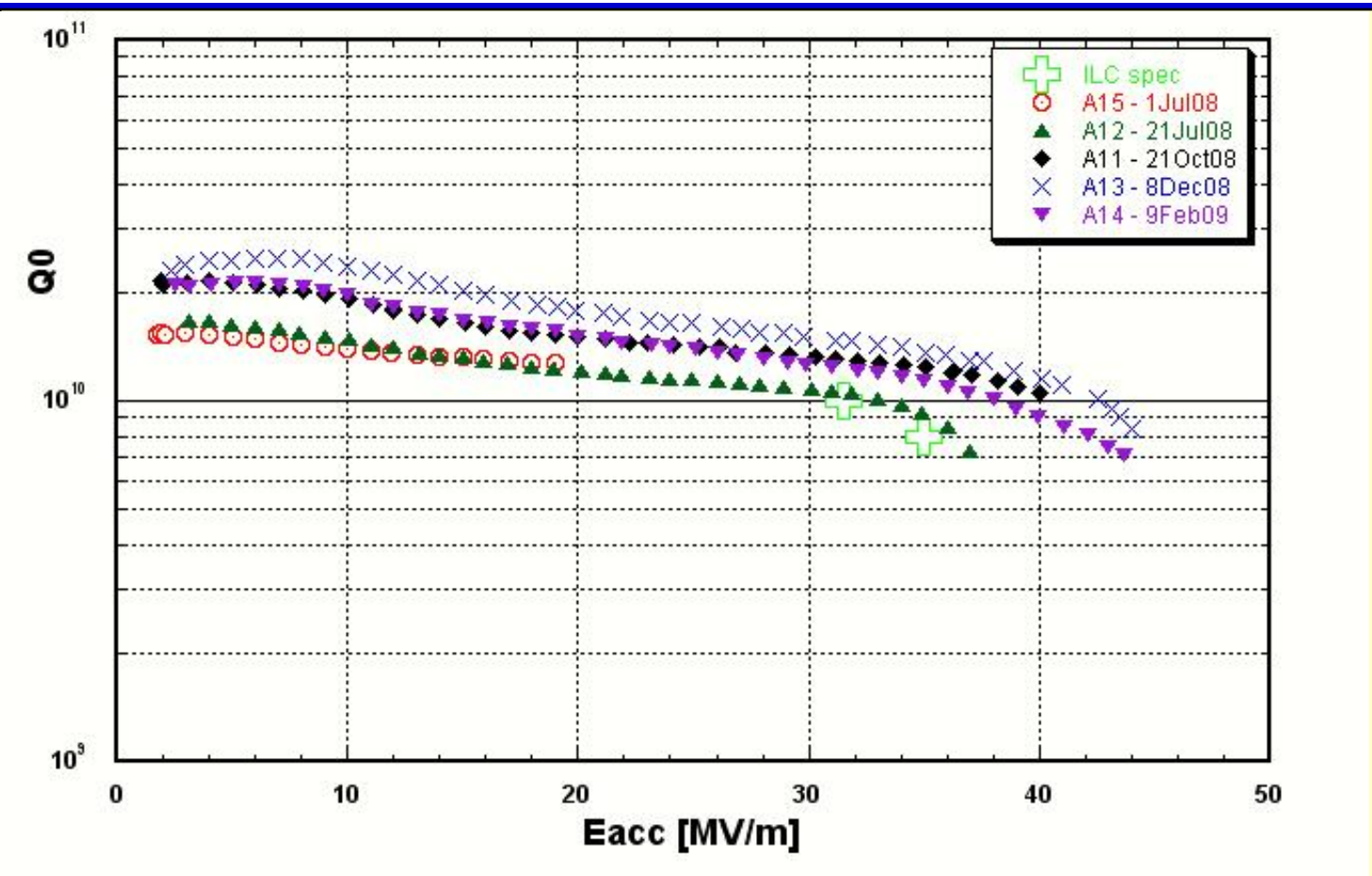
Slide courtesy of Camille Ginsburg, FNAL

February 2009



Most Recent Results from JLab

as of Feb. 18, 2009



Four cavities made ILC spec the first time

One had a material defect which caused a low gradient quench

Slide courtesy of **Rongli Geng** JLab

- Five 9-cell cavities: built by ACCEL, and processed/tested at JLab
- All of them processed with one bulk EP followed by one light EP and ultrasonic pure-water cleaning with detergent (2%)

ILC Technical Area Group Leader

- Akira Yamamoto & Marc Ross, ILC Project Managers visited JLab on April 2-3 to "discuss the global ILC coordination of SRF cavity gradient R & D and to consider the role that Jefferson Lab could have in this critical effort"

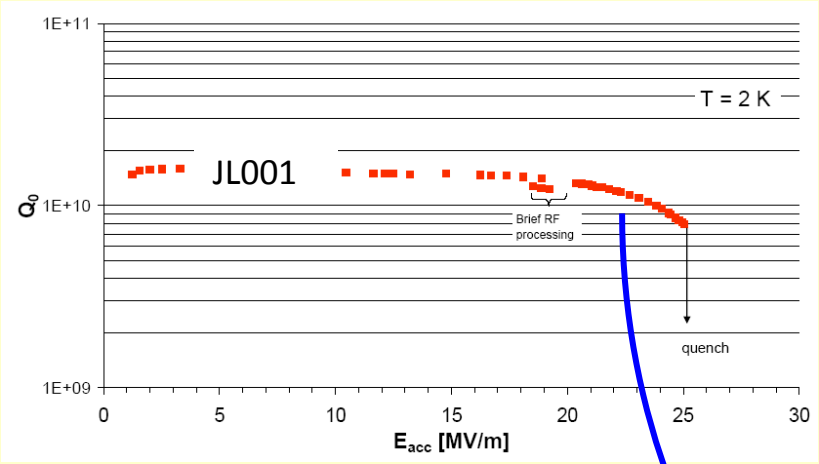
  "The Technical Area Group Leader (is) responsible for coordinating cavity gradient R & D … propose that Jefferson Lab consider nominating a researcher or an engineer (to) take the responsibility for that role"

  "JLab is and will continue to be the Center Of Excellence for SCRF Cavity technology, research and development"

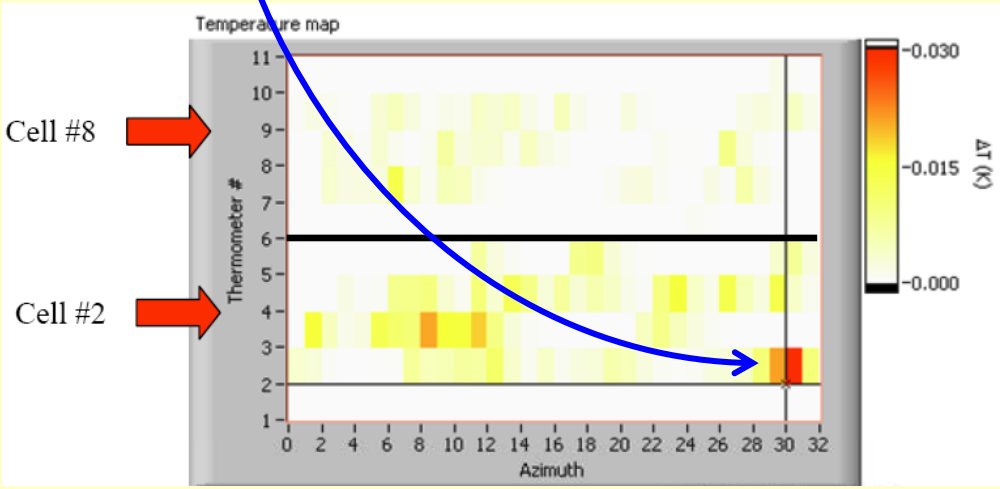
- JLab agreed to take technical leadership in SRF cavity gradient R&D, and proposed Rongli Geng for the position of ILC Technical Area Group Leader

Thermometry for Localizing Hot Spots

A 2-cell thermometry system for ILC 9-cell cavity was designed, built and commissioned at JLab to study defects

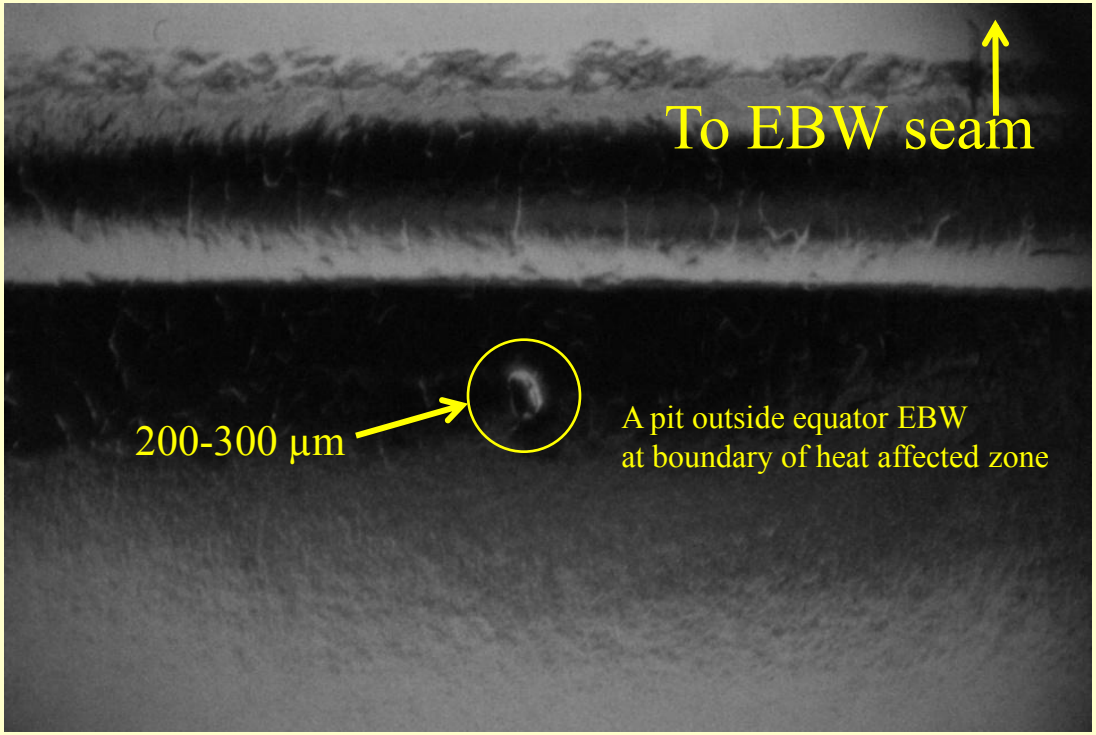


"Hot-spots" were detected near the equator weld of one of the cells, causing the Q-drop

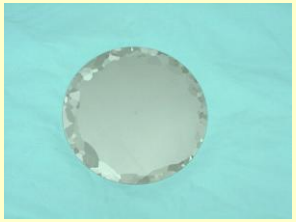


Hi-resolution optical inspection

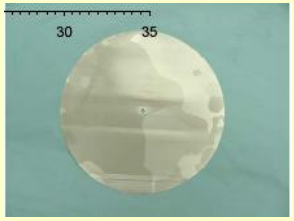
Questar long-range microscope + electro-luminescent (diffuse) source



Large Grain/Single Crystal Niobium

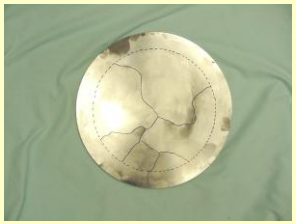


Ingot "A", 800 ppm Ta



Ingot "B", 800 ppm Ta

Ingot "C", 1500 ppm Ta

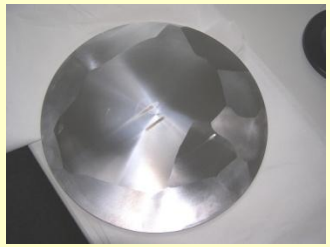


Ingot "D",800 ppm Ta

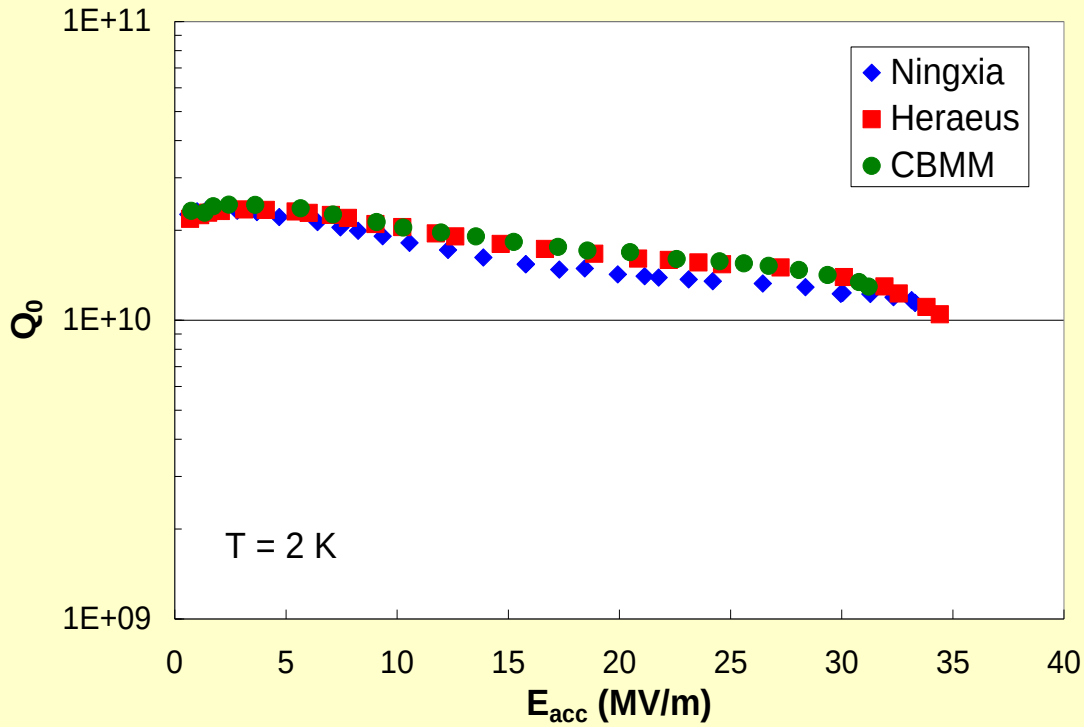
Ninxia

Wah Chang

Heraeus



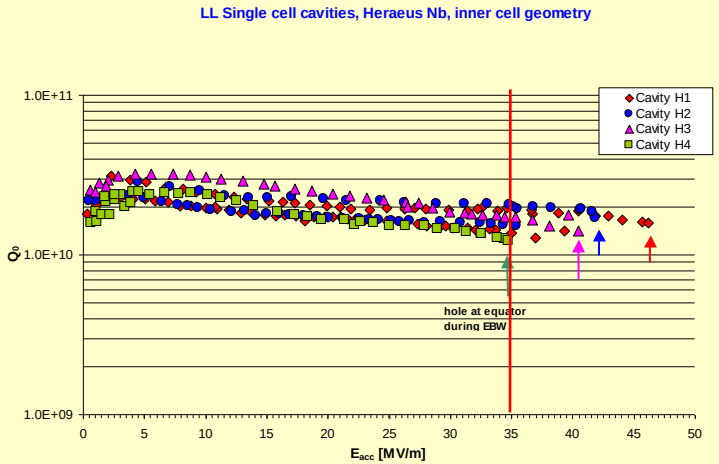
Large Grain/Single Crystal Niobium is a JLab patented cavity material
Ganapati Myneni & Peter Kneisel

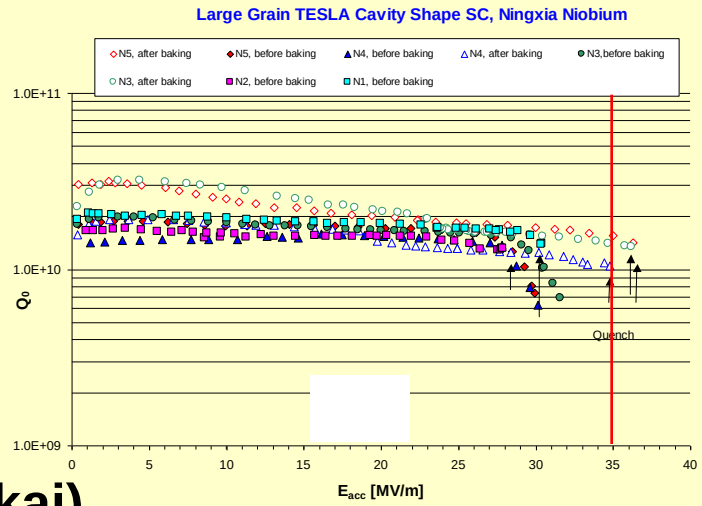


Very consistent results from different vendors, BCP + post-purification

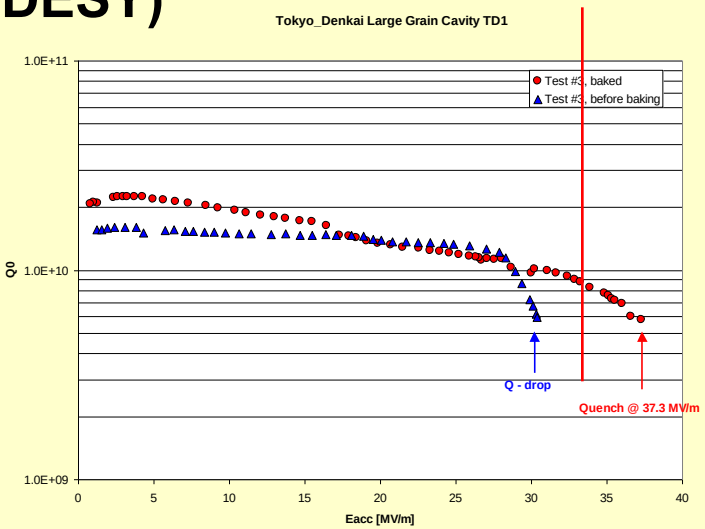
Large grain/Single Crystal Niobium

- **Reproducibility Tests with single-cell cavities from large grain niobium of different manufacturers**



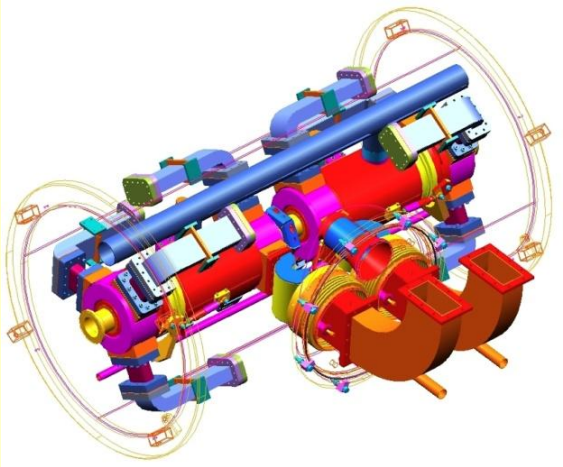


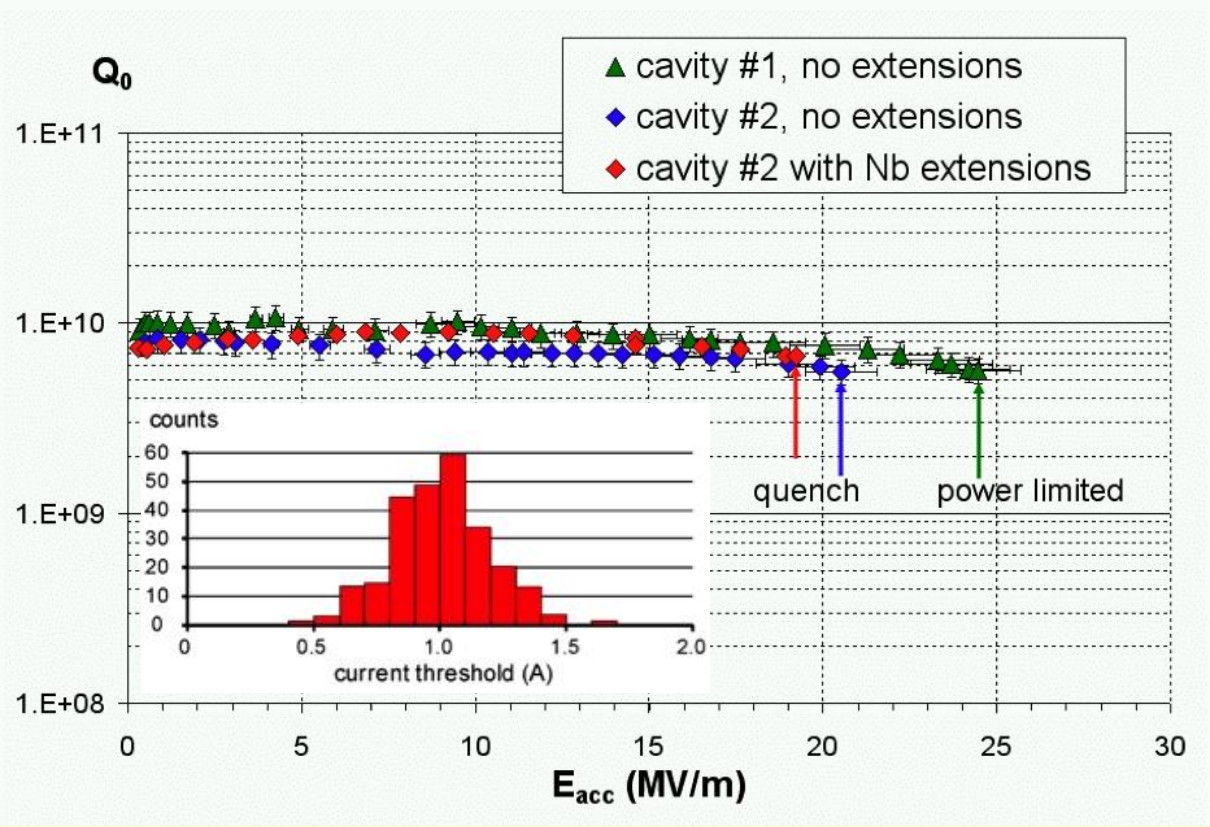
- **Qualification of new vendor (Tokyo Denkai)**
- **Exploration of "rolled single crystal" (w. DESY)**
- **Continued work on 9-cell cavities**
  - **Barrel polishing/guided repair**
  - **2 new LG LL cavities in fabrication**



JLab high-current cryomodules

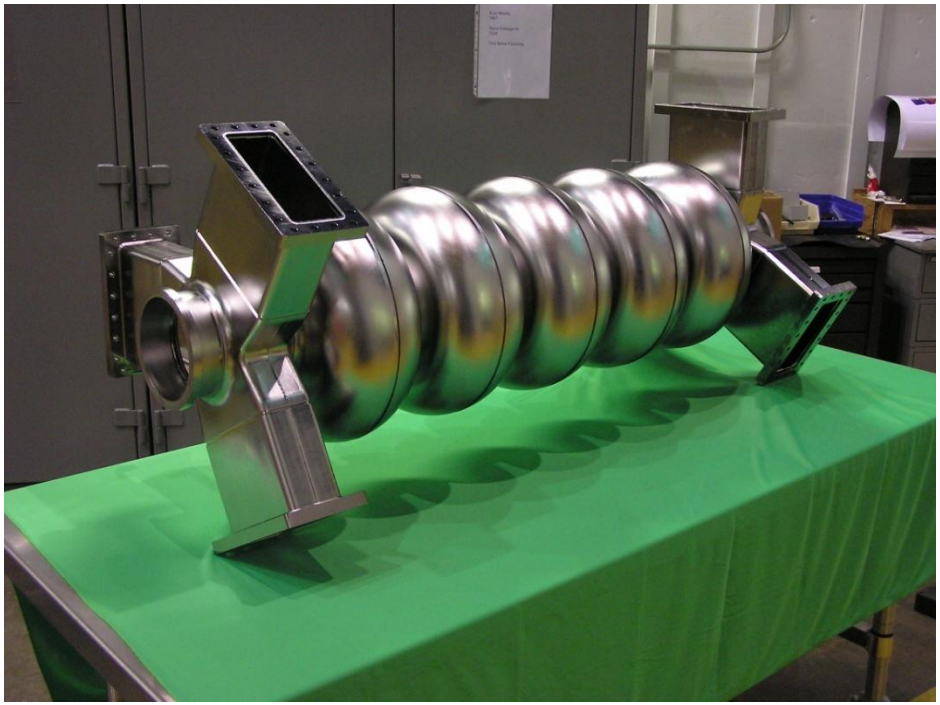
- **Two full 1.5 GHz prototypes of FEL high current cavity built and tested**
  - **Results exceed requirements for 4th gen. light source**
  - **Aiming to build demo cryounit for beam test in FEL injector**

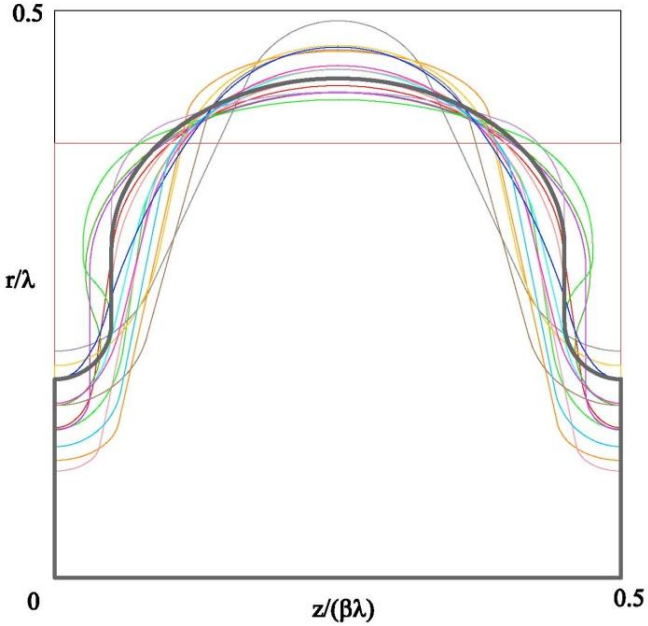


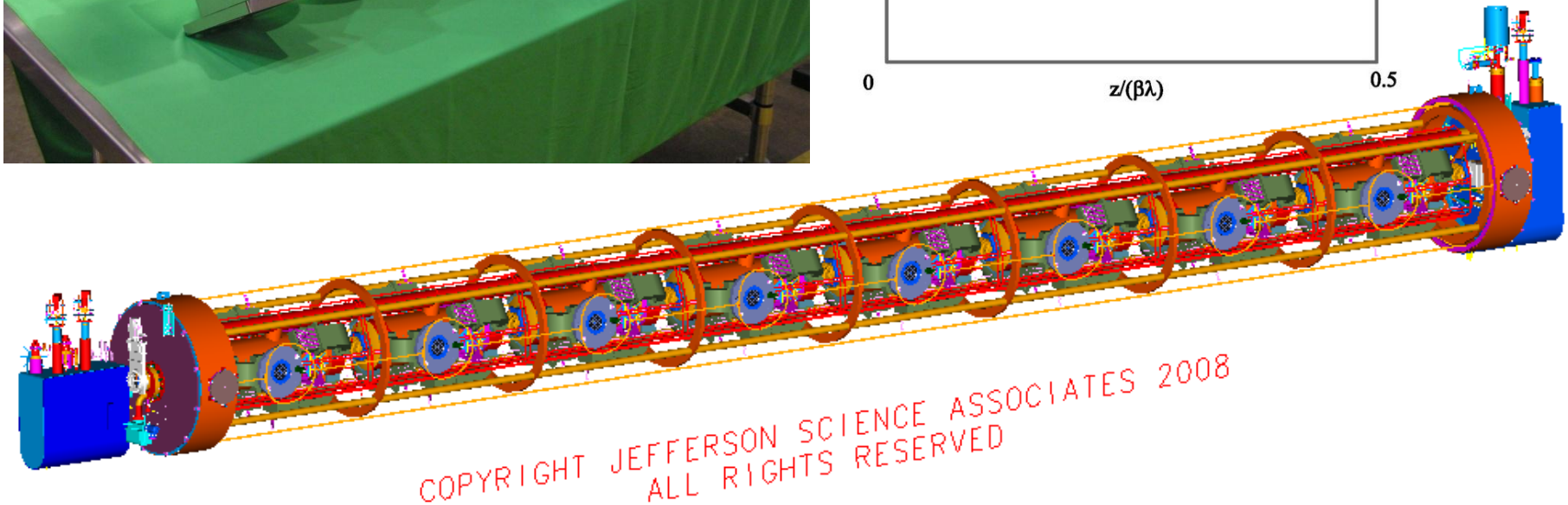


750 MHz 8-cavity cryomodule

Cavity shape optimized to minimize higher order modes





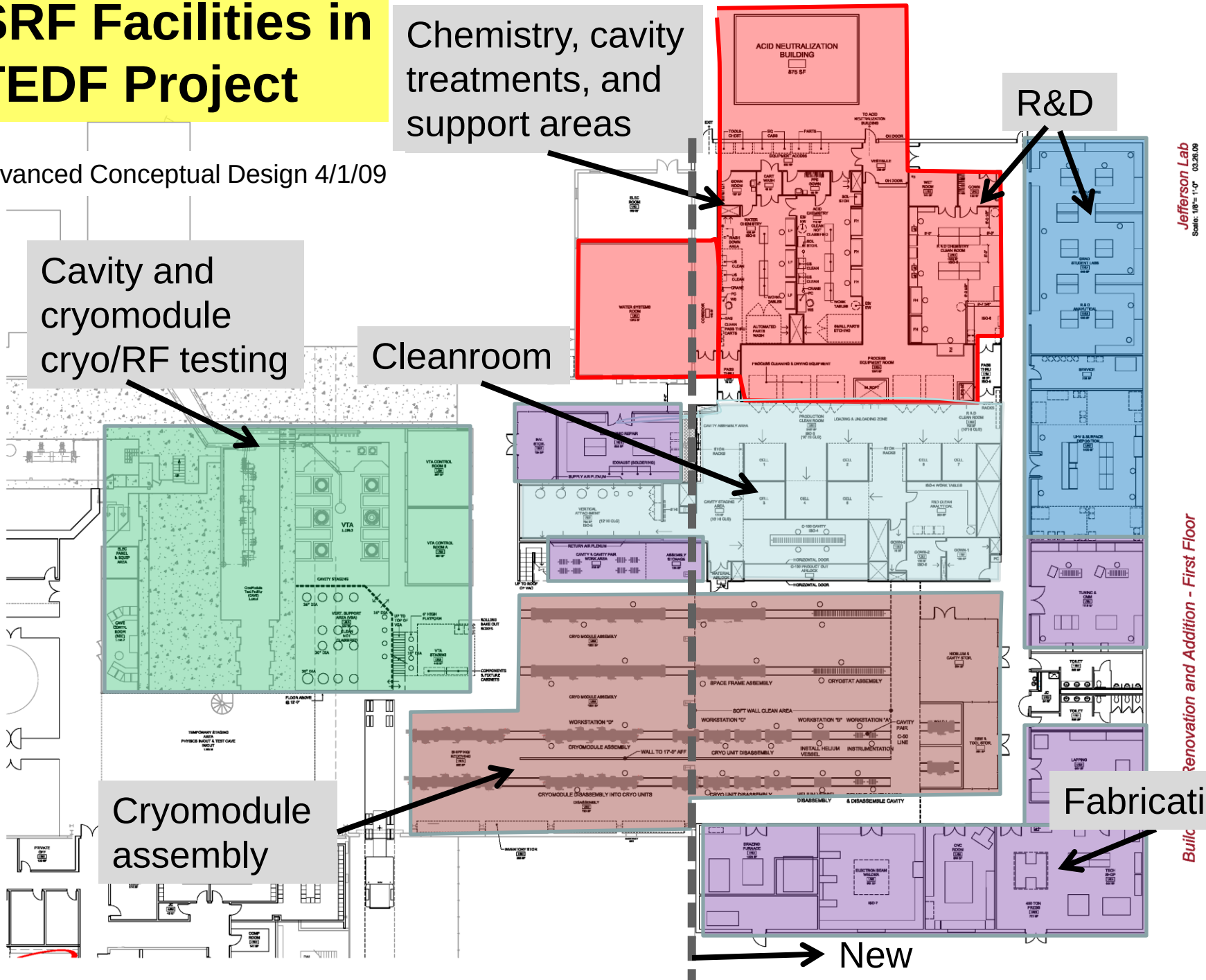


SRF Business Plan

- We have developed a business plan based on estimated future needs for manufacturing (~75%) and R&D (~25%)
- Production capacity equivalent to:
  - 2 cryomodules per month
  - 16 multi-cell cavities per month
- New TEDF Building is designed around this capacity

SRF Facilities in TEDF Project

Advanced Conceptual Design 4/1/09

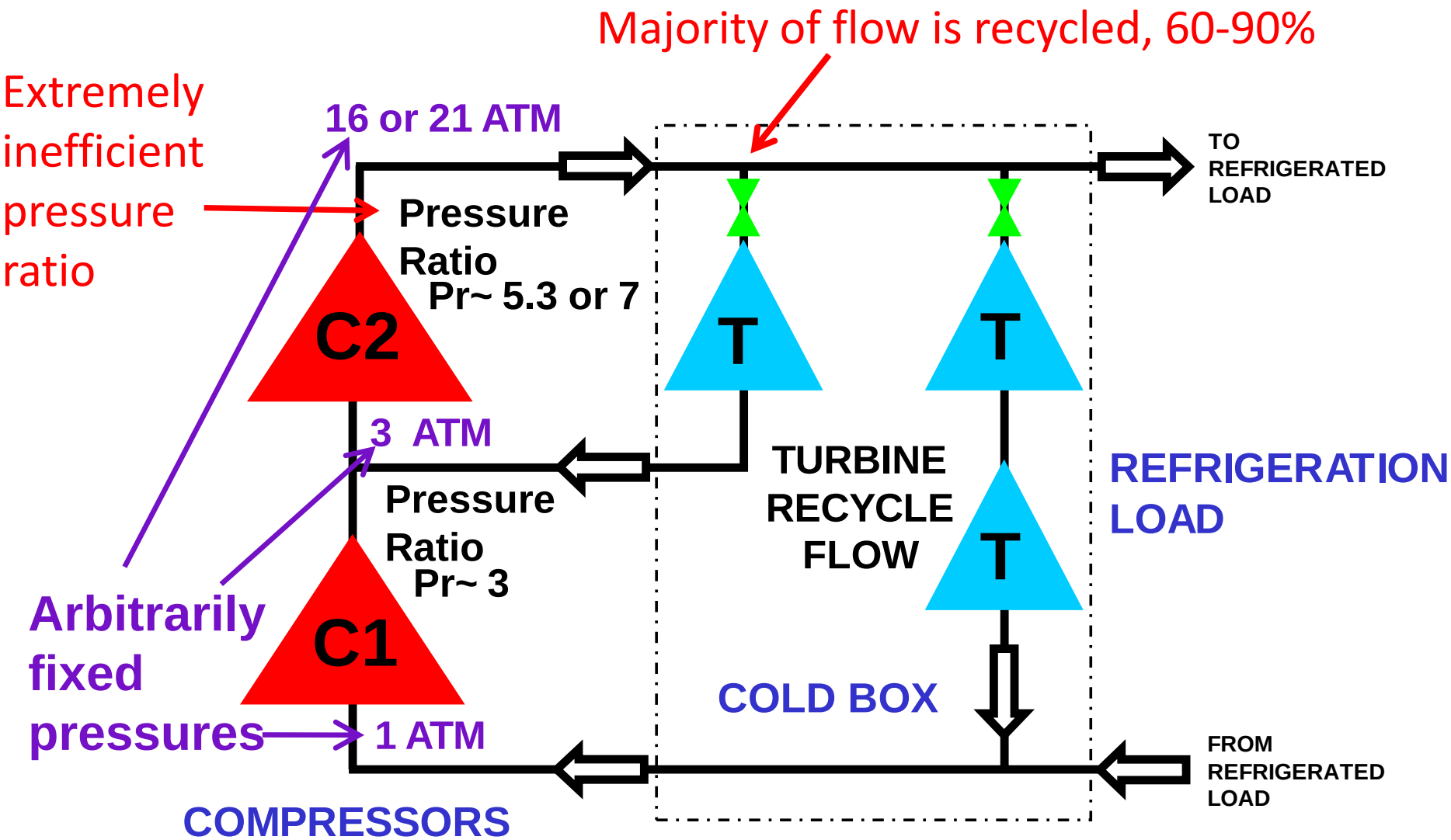


Collins Cryogenics Institute

- R+D centered on both large and small helium refrigeration system operational efficiencies and system cost
- Advanced degree thesis work integrated into the R&D activities
- Primary success derives from a JLab patented process cycle – the "Ganni Cycle" (named for Rao Ganni, JLab)
  - Demonstrated success both here and elsewhere

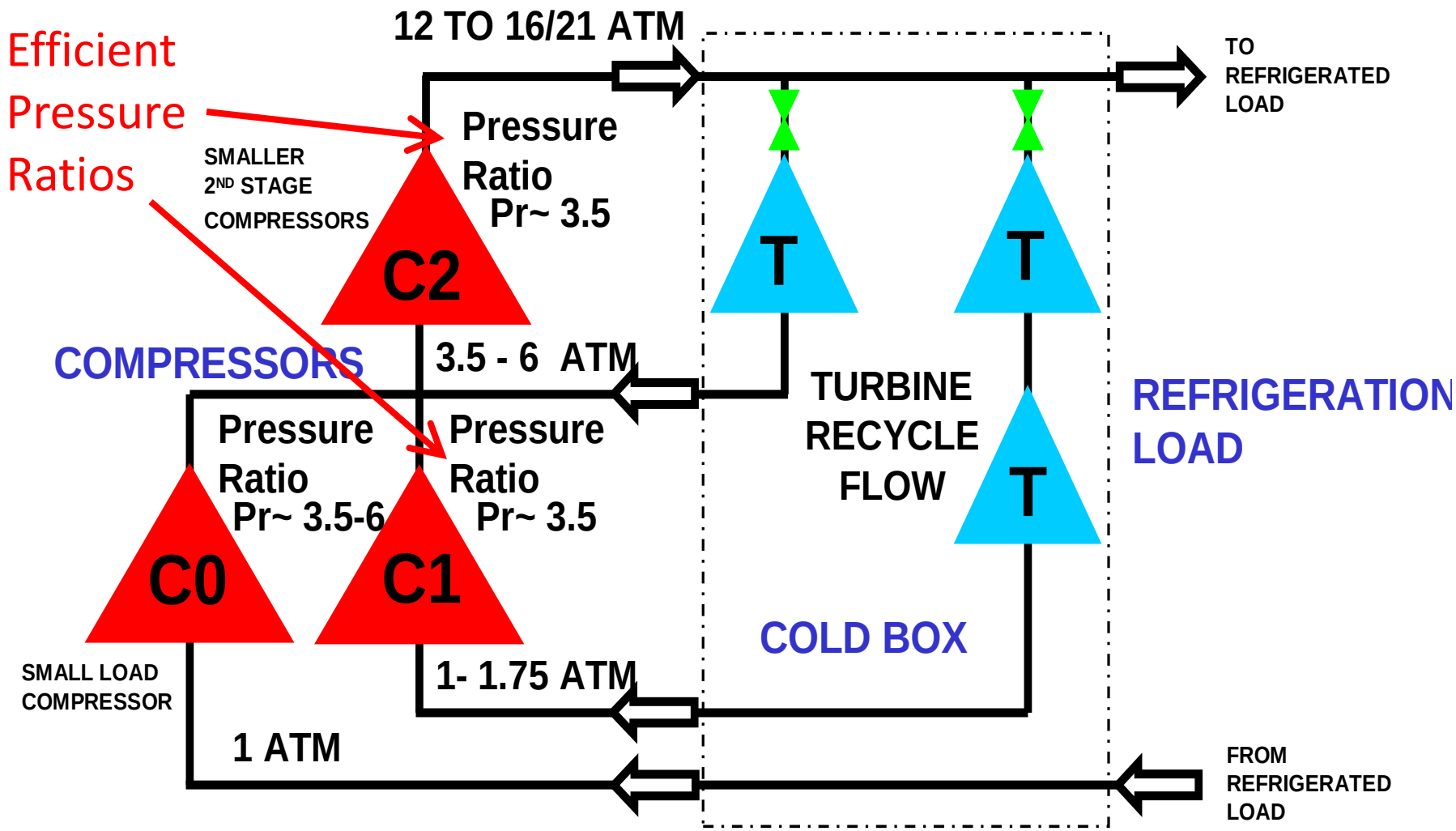
- The Institute receives substantial funding from external sources for common development interests
  - JLab projects have benefited
    - E.g. the JLab 12 GeV helium refrigeration system was co-designed with NASA plant

Simplified Standard Helium Cycle



STANDARD INDUSTRIAL HELIUM REFRIGERATION SYSTEM

Simplified "Ganni Cycle"



GANNI CYCLE (FLOATING PRESSURE)
HELIUM REFRIGERATION SYSTEM

Implementation of Ganni Process Cycle

Existing Plant Conversions (Floating Pressure - partial "Ganni Cycle")

- Jefferson Lab...all six refrigerators, 2K/4K, 200 to 4.6 kW Capacities
- Brookhaven RHIC ….Central Helium Liquefier
- Spallation Neutron Source (SNS)…Central Helium Liquefier 2.3 kW @ 2.1K
- Michigan State University….Cyclotron Test Facility
- NASA Johnson Space Center, Environmental Test Chamber A, twin 3.5 kW 20K refrigerators

Facilities Under Construction (Full Implementation of "Ganni Cycle")

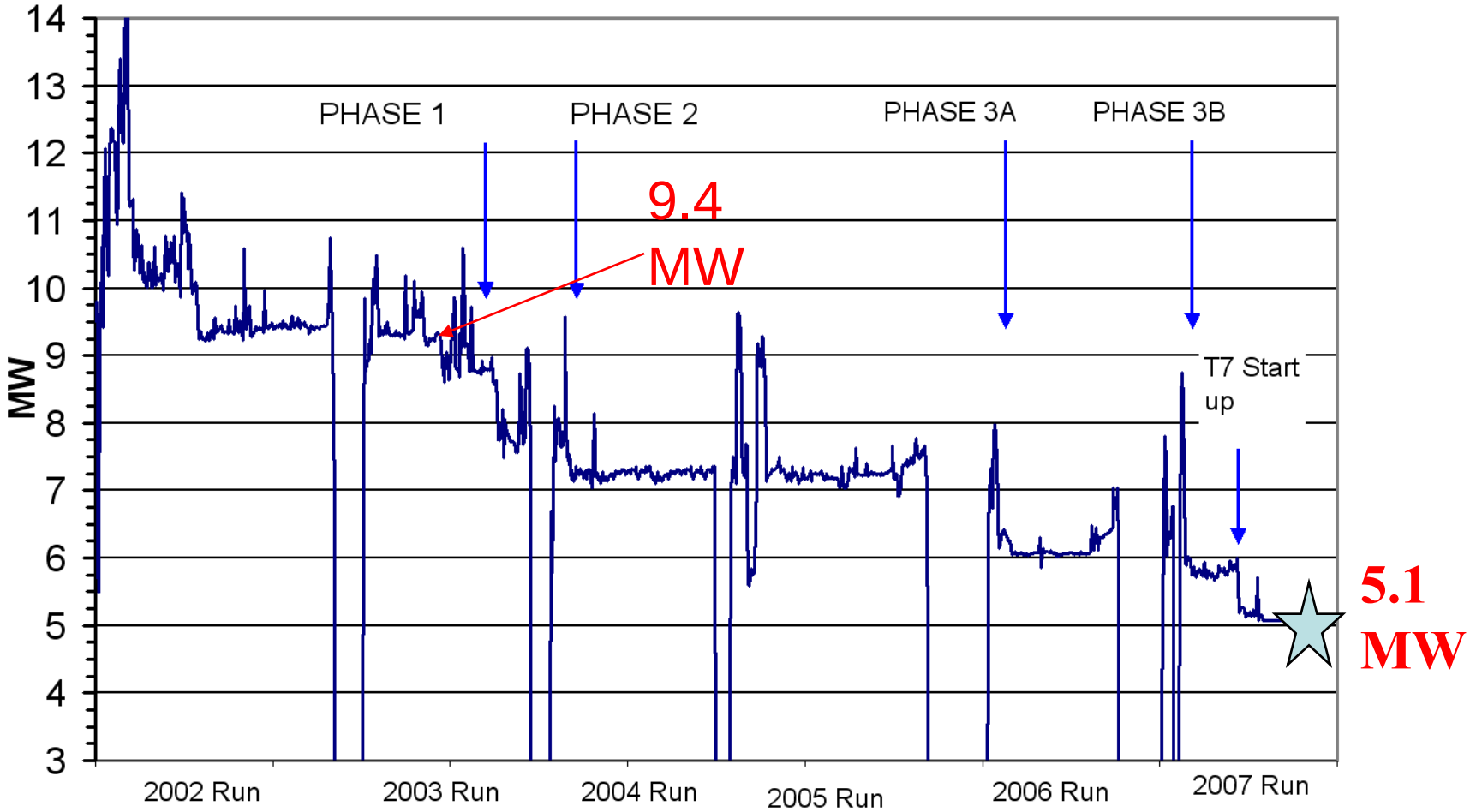
- Jefferson Lab 12 GeV Upgrade, 4.6 kW @ 2.1K
- Jefferson Lab's 4kW End Station Refrigerator (ESR-2)
- NASA Houston, James Webb Telescope Test Facility, 12.5 kW @ 20K

Other Possible Facilities for full implementation of Cycle

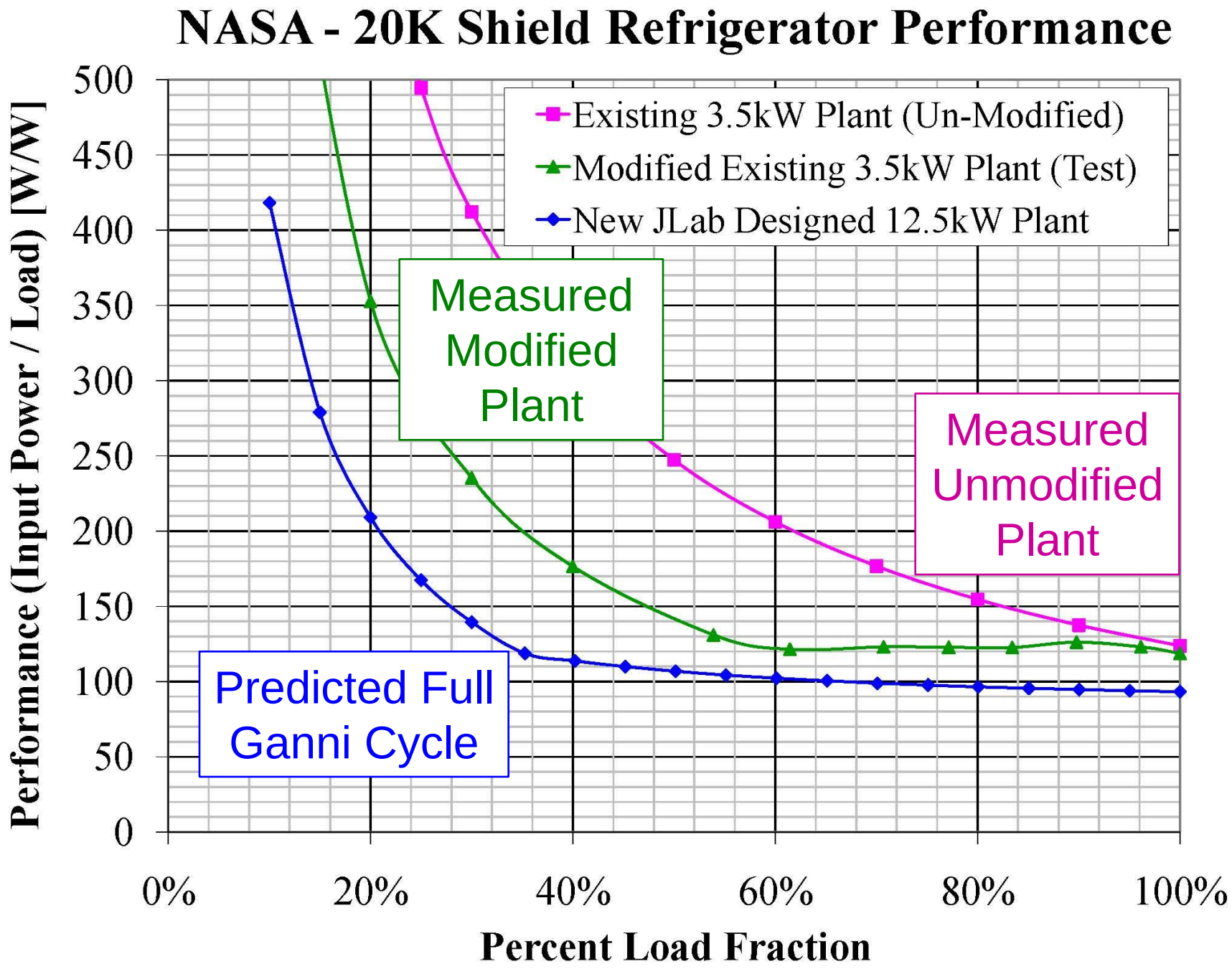
- FRIB, Project X, FEL programs, many others

BNL RHIC Energy Savings Phase III Results

Electric Power History Graph, (Phase III "Goal" 5.4MW)



Exceeded 2003 Goal of 5.4MW……46% Electrical Power Reduction


NASA - 20K Shield Refrigerator Performance
Performance (Input Power / Load) [W/W]
500
450
400
350
300
250
200
150
100
50
0
0%
20%
40%
60%
80%
100%
Percent Load Fraction
Existing 3.5kW Plant (Un-Modified)
Modified Existing 3.5kW Plant (Test)
New JLab Designed 12.5kW Plant
Measured Modified Plant
Measured Unmodified Plant
Predicted Full Ganni Cycle

Demonstrated Results So Far

- General Results of All Users
  - Lower required electrical and cooling water requirement
  - Smaller equipment foot print
  - Greater system temperature stability
  - Reduction in required emergency repair and planned maintenance
- At Jefferson Laboratory (floating pressure)
  - 20% reduction in CHL electrical and cooling requirement
    Example: 6.5 MW to 5.2 MW reduction
  - Lower maintenance requirements
    Example: warm helium compressor maintenance intervals lengthen, 35 K to 74 K hrs (far exceeds current industrial standards)

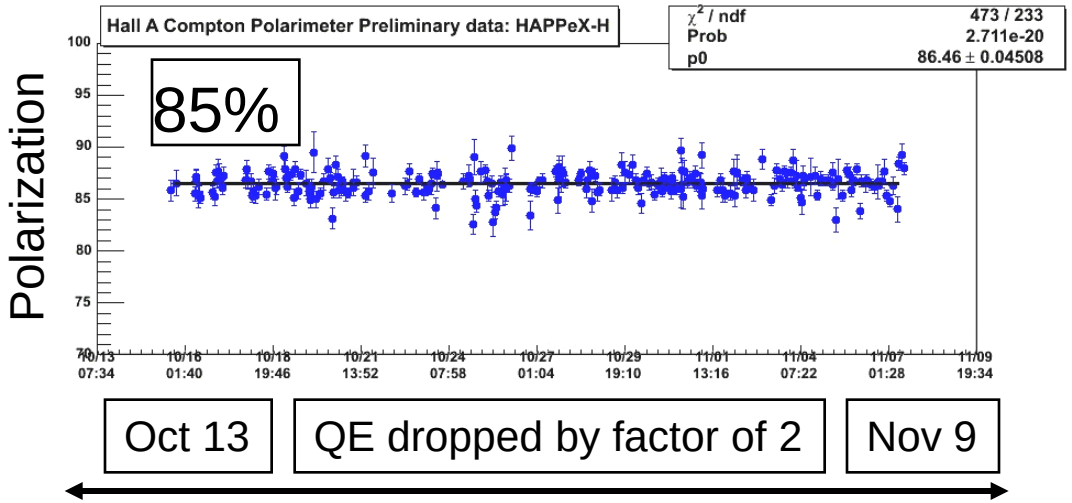
Center for Injectors and Sources

- JLab leads the world in delivery of CW beams
  - At CEBAF, world record polarized beams
    - > 85% polarization measured by the Users at the Hall
    - 16 Coulombs delivered in one 24 hr period
      - An average of 185 μA for 24 hours
    - Load-lock gun has operated at 1 mA in test stand
      - Nearest competitors – Bates 120 μA, Mainz 50 μA
    - Test Cave research to support new initiatives like EIC and ILC
  - At the FEL, world record unpolarized beams
    - > 9 mA achieved daily for months at a time
      - Nearest competitor - Cornell ERL test stand 5 mA

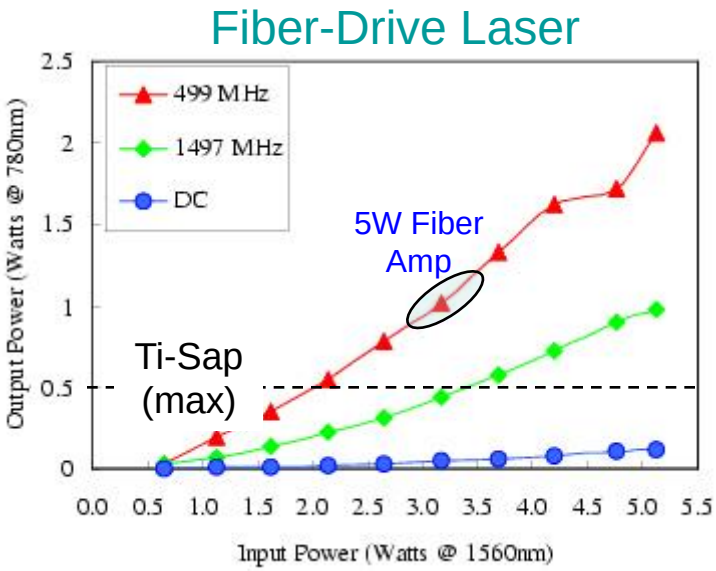
CEBAF Operations

- **Superlattice Photocathodes, polarization ~85% > 80%**
- **Fiber-based drive lasers: powerful and reliable**
- **Load-lock gun key features: transferred to CEBAF**
- **Photocathode lifetime at CEBAF less than at Test Lab**

State of the Art → State of the Process



No depolarization over time!



Parity Violation Specification Summary

Helicity-correlated asymmetry specifications

Experiment	Physics Asymmetry	Max run-average helicity correlated Position Asymmetry		Max run-average helicity correlated Current Asymmetry	
		Spec	**Achieved**	**Spec**	**Achieved**
HAPPEx-I	**13 ppm**	**10 nm**	**10 nm**	**1 ppm**	**0.4 ppm**
G^0 Forward	**2 to 50 ppm**	**20 nm**	**(4 4) nm**	**1 ppm**	**(0.14 0.3) ppm**
HAPPEx-He [2004] HAPPEx-He [2005]	**8 ppm**	**3 nm**	**3 nm** **20* nm**	**0.6 ppm**	**0.08 ppm** **0.1 ppm**
HAPPEx-II-H [2004] HAPPEx-II-H [2005]	**1.3 ppm**	**2 nm**	**8** nm** **1 nm**	**0.6 ppm**	**2.6** ppm** **0.1 ppm**
PREX	**0.5 ppm**	**1 nm**	**-**	**0.1 ppm**	**-**
Q_{weak}	**0.3 ppm**	**20 nm**	**-**	**0.1 ppm**	**-**

* Results affected by electronic crosstalk at injector.

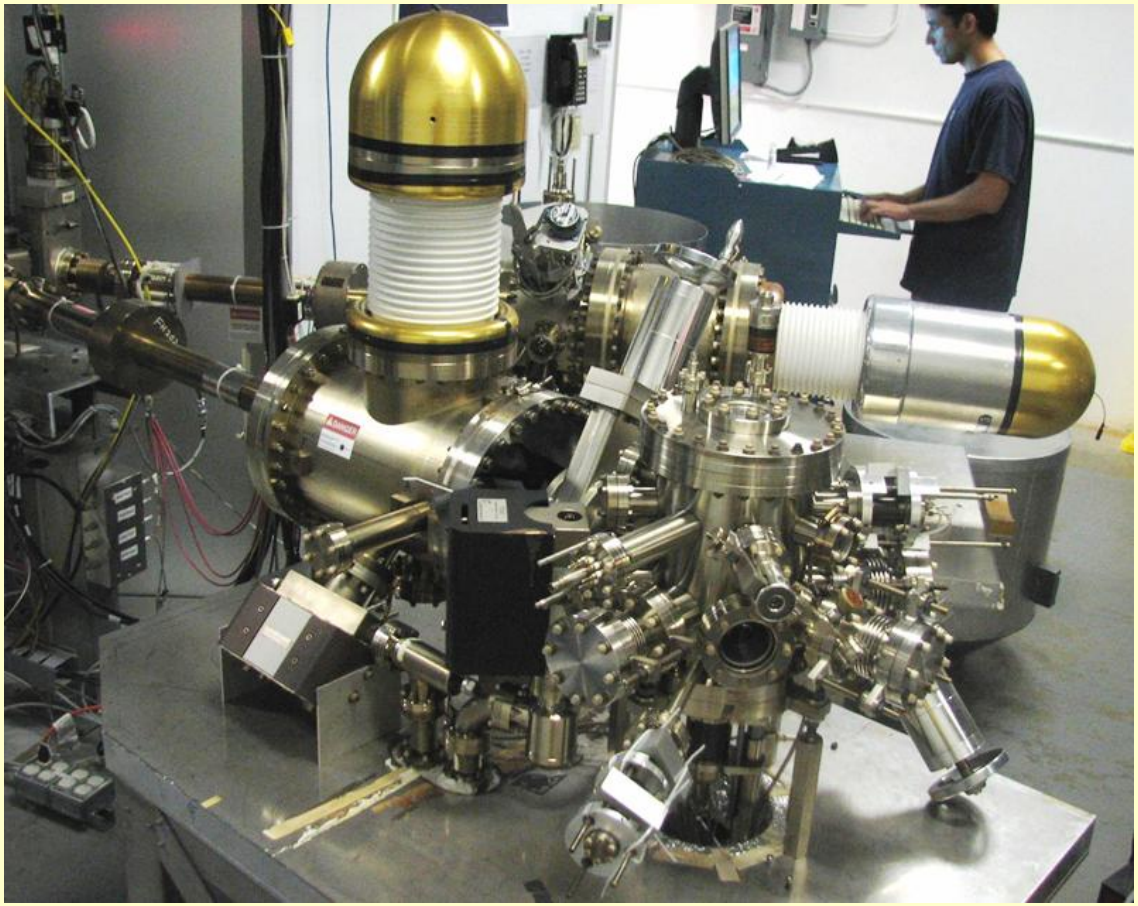
** Results at Hall A affected by Hall C operation. Spec was met in 2005 run.

Higher Voltage Gun

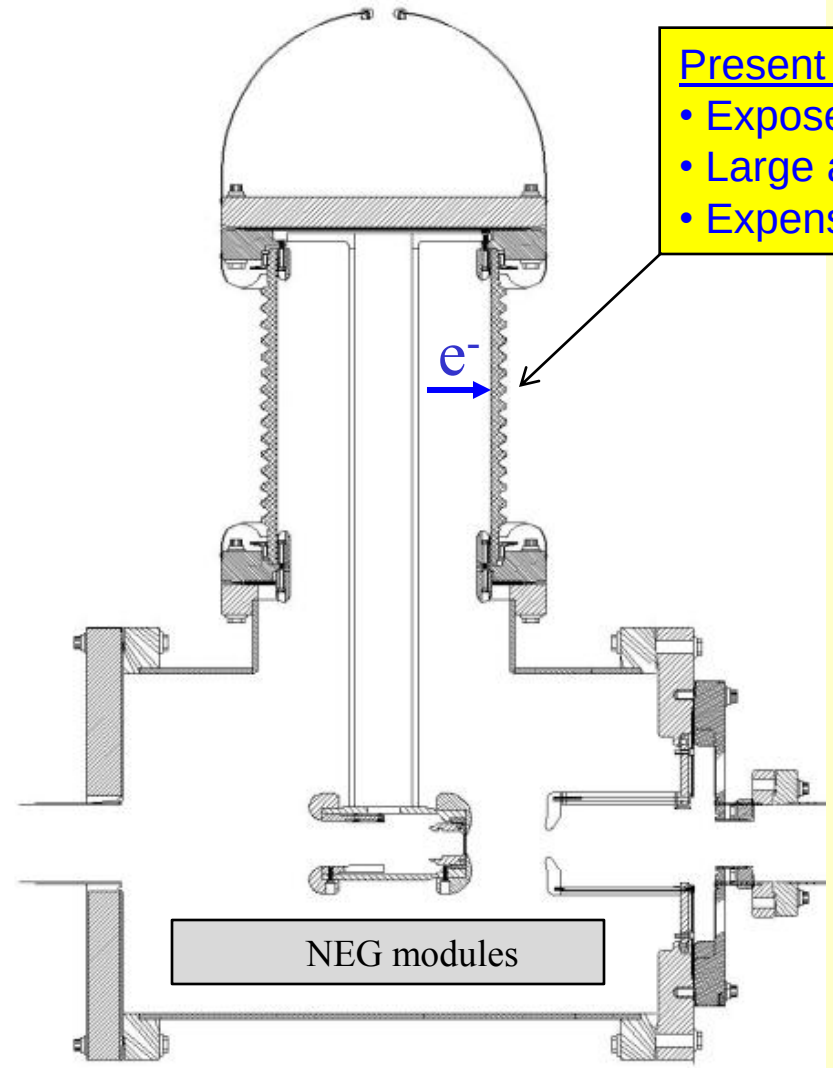
- Helps achieve ALL goals
- More UP time at CEBAF, better beam quality for Parity Violation experiments
- Longer lifetime at high average current, good for FEL and positron source
- Emittance preservation at high bunch charge and peak current

High Voltage Issues:
- Field emission
- Electrode design: reducing gradient and good beam optics
- Hardware limitations at CEBAF (Capture, chopper)

Improve Vacuum
- Ion pumps
- NEG pumps
- Outgassing
- Gauges



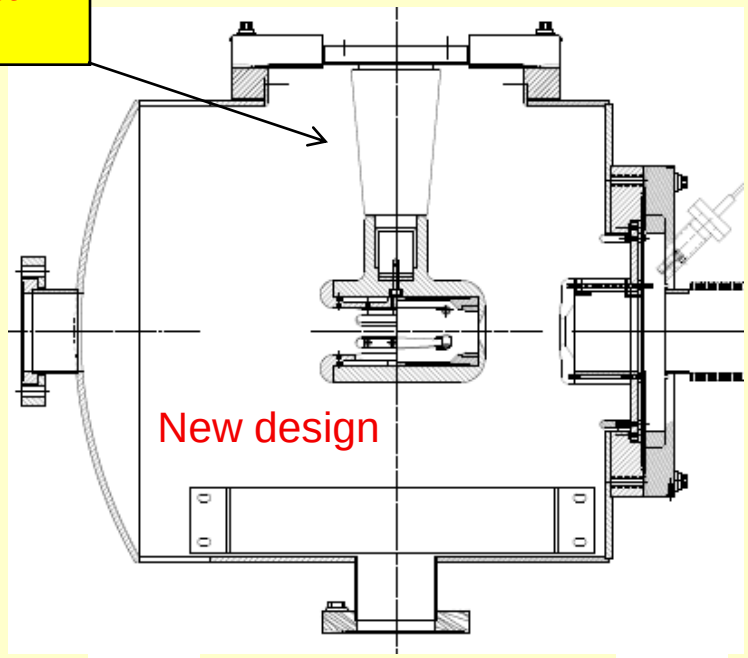
“Inverted” Gun



Present Ceramic
- Exposed to field emission
- Large area
- Expensive (~$50k)

Medical x-ray technology

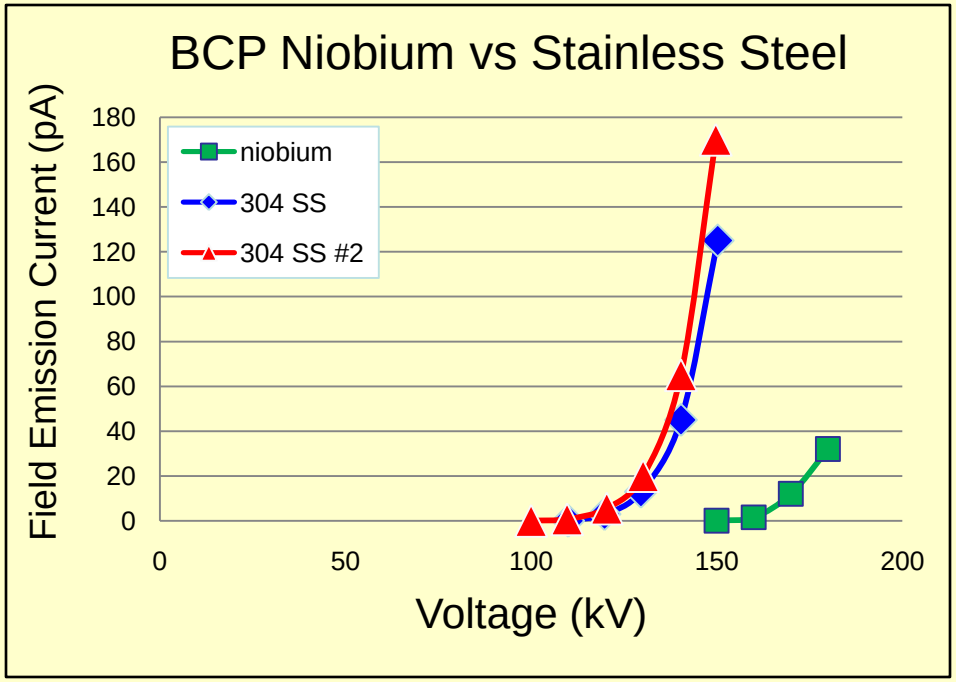
New Ceramic
- Compact
- ~$5k



Move from “conventional” insulator used on **all** GaAs photoguns today – expensive, months to build, damaged by field emission.

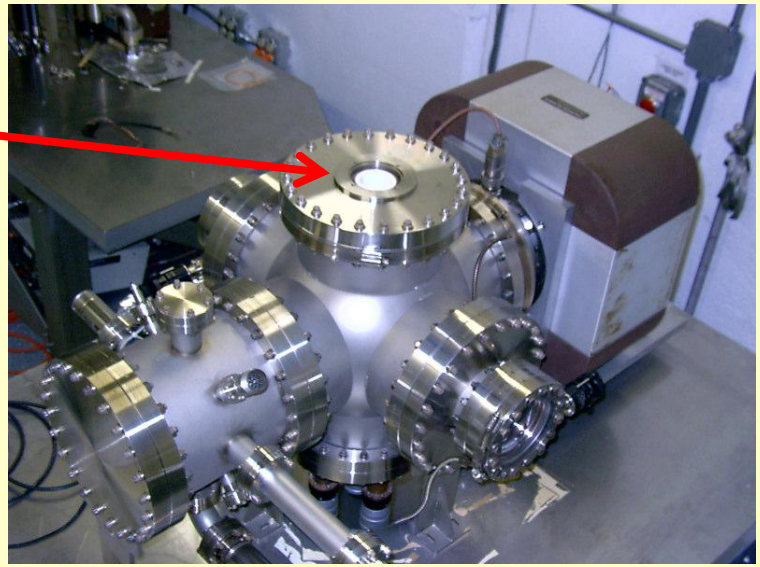
Single Crystal Niobium:

- Capable of operation at higher voltage and gradient
- Buffer chemical polish (BCP) much easier than diamond-paste-polish



Conventional geometry: cathode electrode mounted on metal support structure

Replace conventional ceramic insulator with “Inverted” insulator: no SF6 and no HV breakdown outside chamber



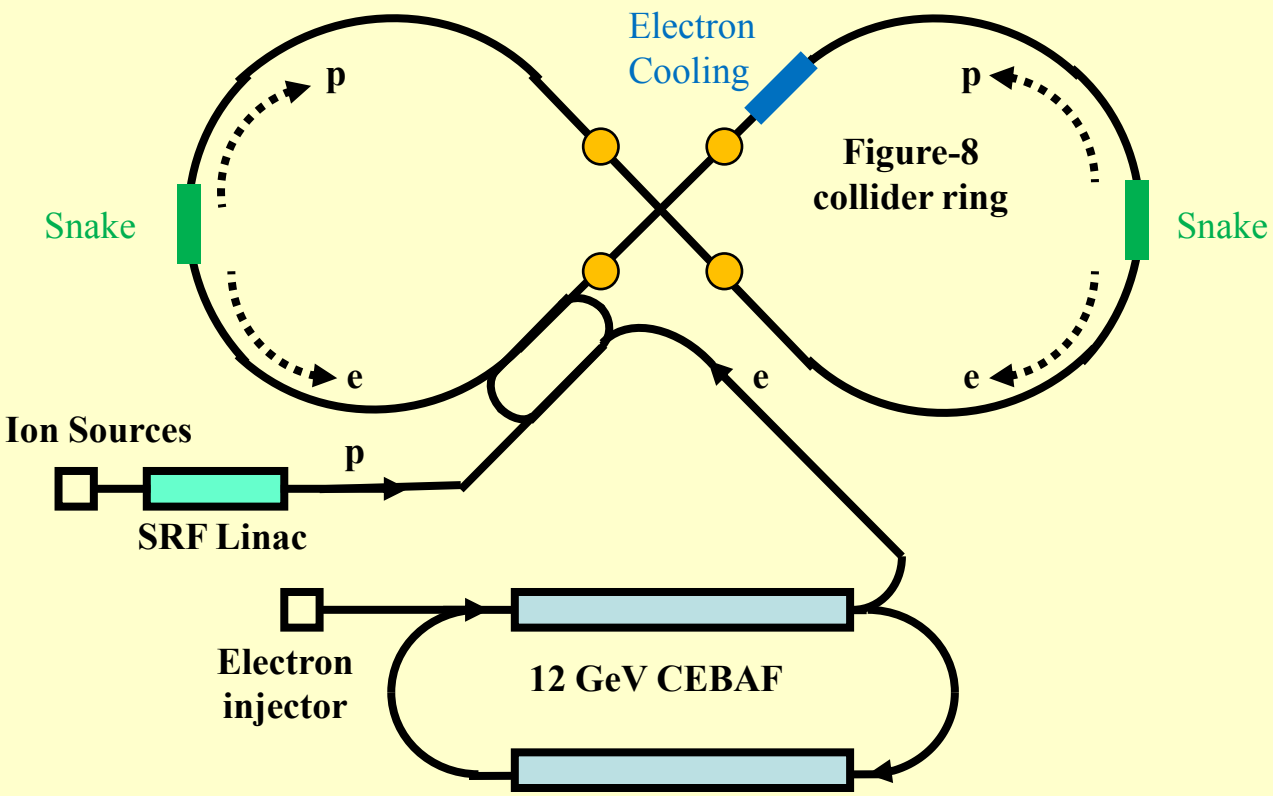
Center for Advanced Studies of Accelerators

- 10 professional staff, 7 graduate students
- Specializing in:
  - Multi-pass linacs
  - Energy recovery linacs
  - Superconducting cavity interactions with electron beam
  - Transport optics
  - Electron Ion Collider design
  - Simulations
- Same group provides optics support to 12 GeV Upgrade, will commission the 12 GeV machine and actively supports the 6 GeV Physics program

ELIC Design Goals

- **Energy**
  - Center-of-mass energy between 20 GeV and 100 GeV
  - Energy asymmetry of ~ 10,
    ➔ 3 GeV electron on 30 GeV proton/15 GeV/n ion up to 10 GeV electron on 250 GeV proton/100 GeV/n ion
- **Luminosity**
  - $>10^{33}$ up to 3×10^{34} $cm^{-2}s^{-1}$ per interaction point
- **Ion Species**
  - Polarized H, D, $_3$He, possibly Li
  - Up to heavy ion A = 208, fully stripped
- **Polarization**
  - Longitudinal polarization at the IP for both beams
  - Transverse polarization of ions
  - Spin-flip of both beams
  - All polarizations >70% desirable

ELIC Conceptual Design



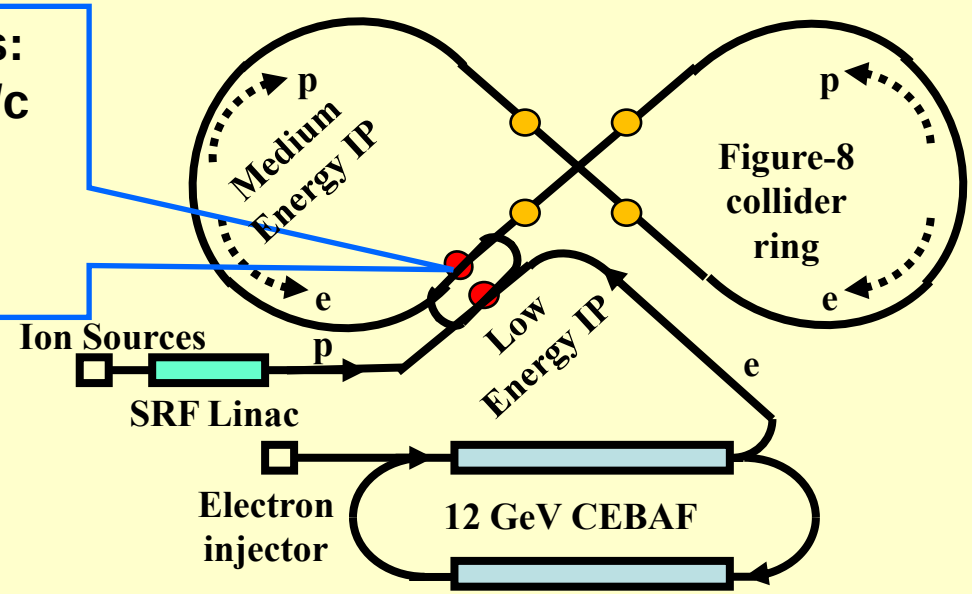
ELIC (p/e) Design Parameters

Beam energy	GeV	250/10	150/7	50/5
Figure-8 ring	km	2.5		
Collision freq	MHz	499		
Beam current	A	0.22/0.55	0.15/0.33	0.18/0.38
Particles/bunch	10^9	2.7/6.9	1.9/4.1	2.3/4.8
Energy spread	10^{-4}	3/3		
Bunch length, rms	mm	5/5		
Hori. emit., norm.	μm	0.70/51	0.42/35.6	.28/25.5
Vertical emit., norm.	μm	0.03/2.0	0.017/1.4	.028/2.6
β^*	mm	5/5		
Vert. b-b tune-shift		0.01/0.1		
Peak lum. per IP	10^{34} cm^{-2}s^{-1}	3.0	1.2	1.1
Number of IPs			4	
Luminosity lifetime	hours	24		

Electron parameters are red

MEIC & Staging of ELIC

The tunnel houses 3 rings:
Electron ring up to 5 GeV/c
Ion ring up to 5 GeV/c
Superconducting ion ring for up to 30 GeV/c

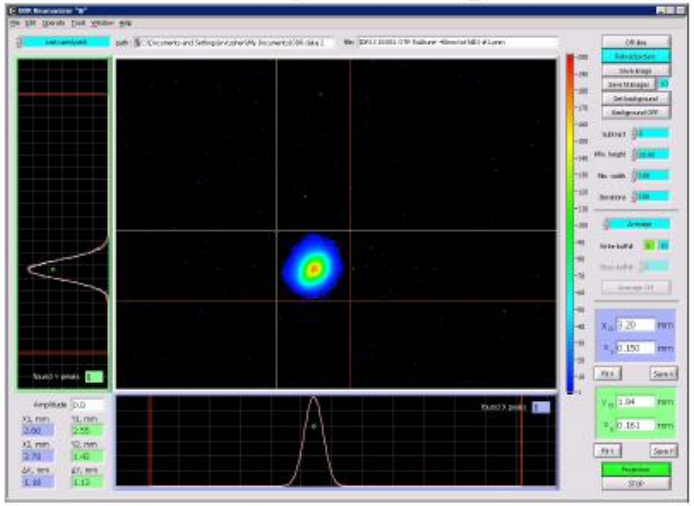


	Stage	Maximum Momentum (GeV/c)		Ring Size (m)		Ring Type	
		Proton	Electron	Ion	Electron	Ion	Electron
1	Low Energy	5	5	400	400	Warm	Warm
2	Medium Energy (MEIC)	30	5	400	400	SC	Warm
3	Medium Energy	30	10	400	1800	SC	Warm
4	High Energy (ELIC)	250	10	1800	1800	SC	Warm

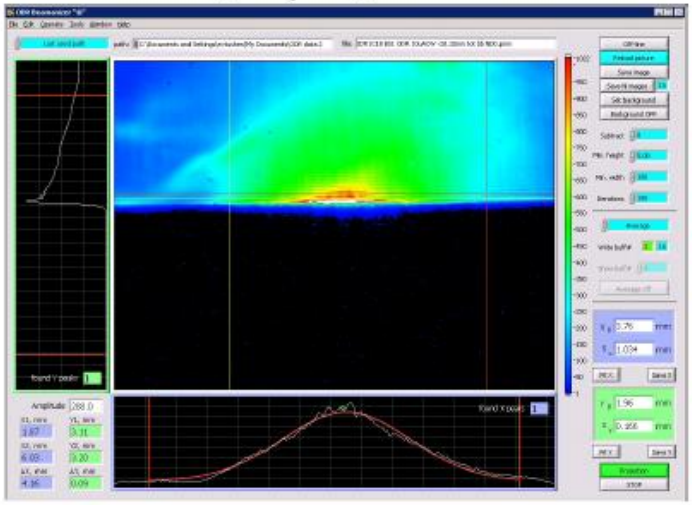
Optical Diffraction Radiation (ODR) monitors

- **Non-invasive beam size monitor**
  - **Variant of Optical Transition Radiation (OTR)**
  - **Charge passes near (~5σ) a metal edge**
  - **Electric field induces charge in metal**
  - **Collapse of the image charge results in radiation, some of it in the visible region**
  - **Observed image can be related to beam size**

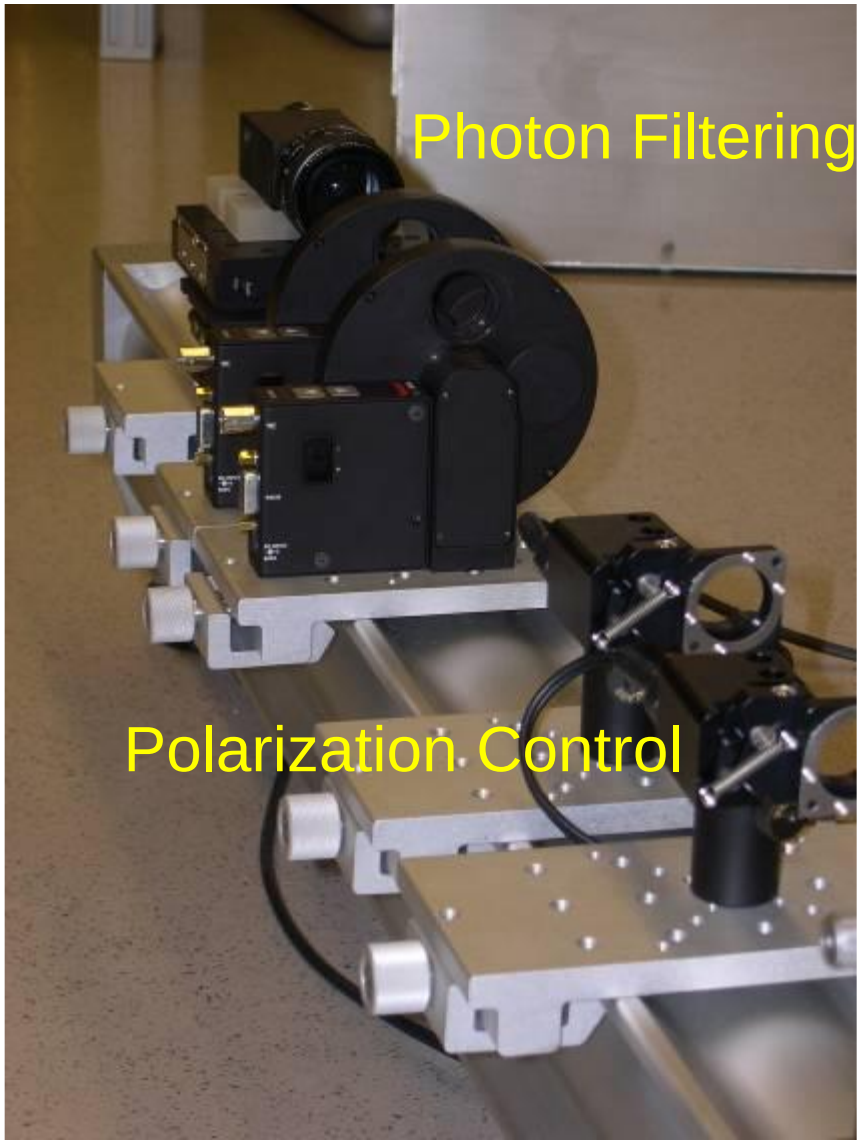
OTR beam spot image



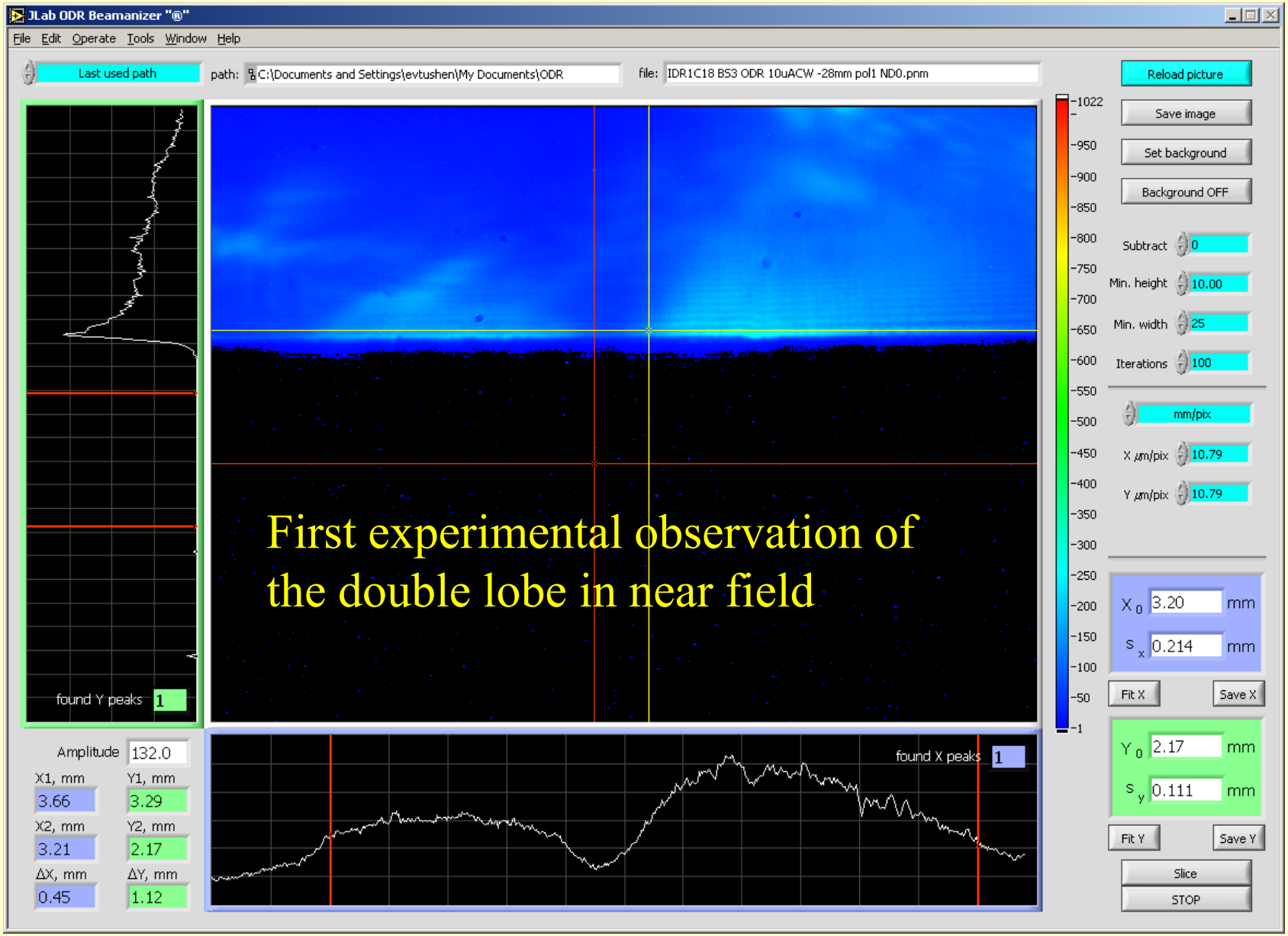
ODR image (edge 5σ from beam)



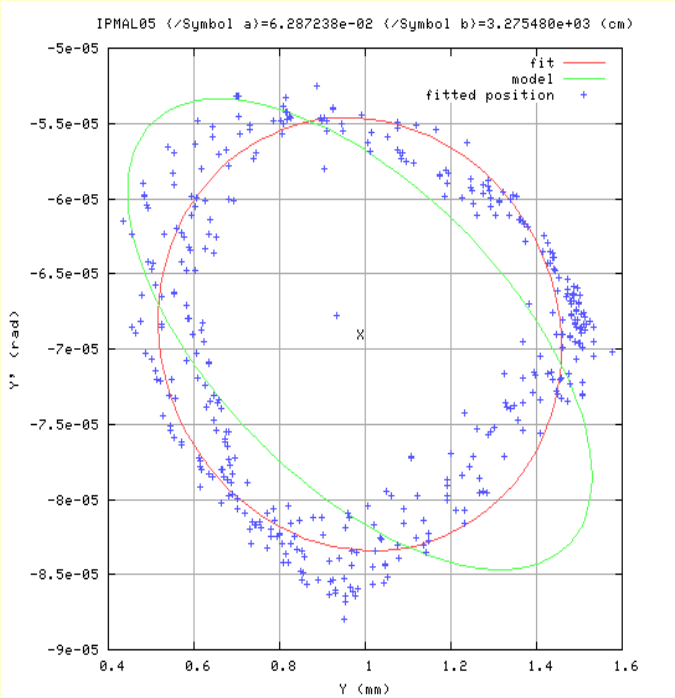
ODR SETUP IN TUNNEL

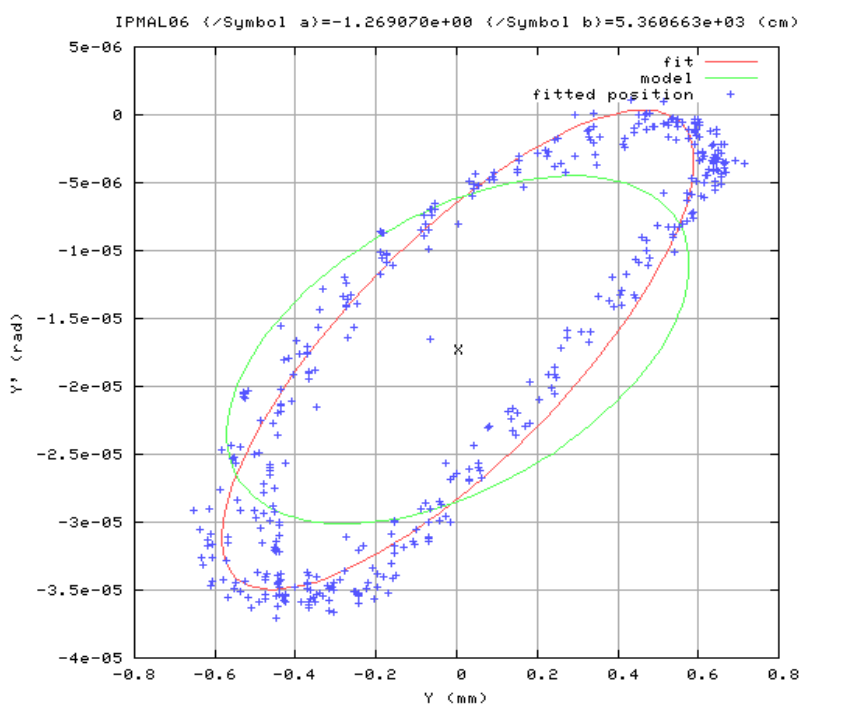


10 μA CW beam, ODR H-polarized



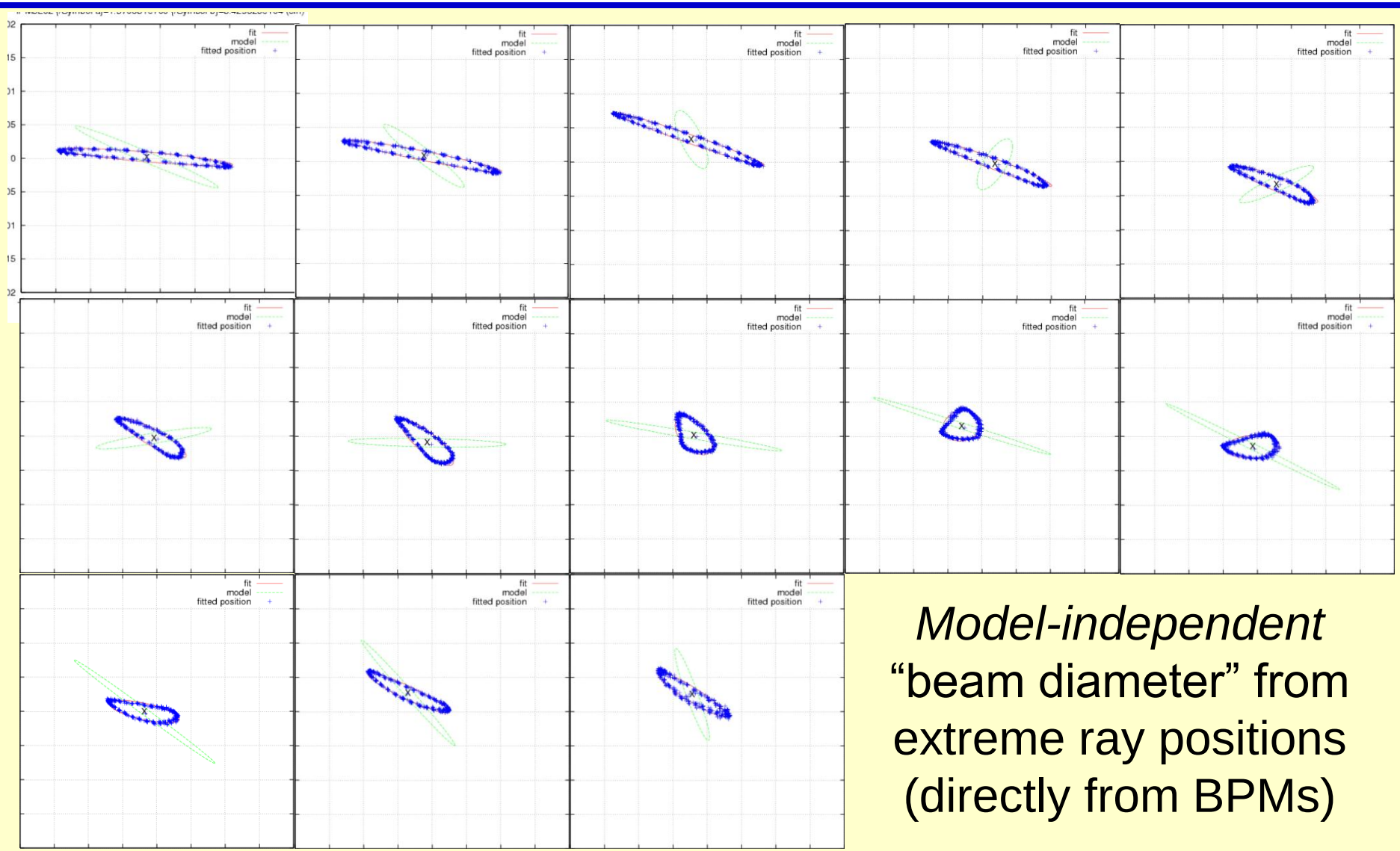
‘RAY-TRACE’ beam matching tool





- **Unique tool for deterministic beam envelope (re)matching**
- **Synthetic beam visualization tool – beam sizes from BPMs**
- **Diagnostic tool for nonlinear effects in Spr/Rec regions**
- **Essential step for ‘Model based’ machine setup**

Measured Analog ray trace thru 3rd pass North Linac



Model-independent "beam diameter" from extreme ray positions (directly from BPMs)

External Partnerships

Cross-Project R&D Funding

- We seek R&D funding from any project that needs our core competencies
  - We can be a cost-effective R&D partner because of our present experience
  - But carrying out the R&D will reinforce our leadership in our core competencies
    - Will make us even more cost-effective in the future
- Examples
  - Digital RF controls funded jointly by 12 GeV and RIA
  - High efficiency cryogenics funded by NASA (12 GeV)
  - High current cavities funded by ONR (electron cooling)
  - High voltage guns funded by ILC (6 GeV)
  - Crab cavities funded by APS (ELIC)

Partnerships, Actual and Under Negotiation

- JLab participation is based on SRF technology and cryogenics, backed by accelerator theory, diagnostics and, in two cases, injectors

1. ILC
2. Japan-USA Cooperation Agreement
3. PUP (Power Upgrade Project) at SNS
4. APS at ANL

Receiving funds now

5. Project X at Fermilab
6. FRIB at MSU
7. FEL at LBNL
8. Cornell ESR (new this week)

Education

Accelerator Education Activities at JLab

- Staff with University Affiliation 11
- Staff who taught at USPAS 3
- Staff who mentor graduate students 9
- Staff who taught abroad 2
- Graduate students *Present* Graduated '0*1- '08*
  - PhD 19+4* 9
  - Masters 2* 3
- In addition,
  - 1 ODU undergraduate thesis was completed in 2008
  - High school students are mentored in special topics during the school year

*Staff Members

Old Dominion University (ODU)

- We have created a Center for Accelerator Science at ODU
  - Director of the Center jointly funded by JLab and ODU
    - Excellent candidates, negotiating with top candidate
  - JLab/ODU now receives a grant from NSF (REU) for undergraduate research opportunities
    - 4 students first year, 8 students this year
  - JLab staff teaching one graduate level course in Low Temperature Physics (Jean Delayen) and one Introduction to Accelerator Physics to senior undergraduate/graduates (Geoff Krafft)

Idaho State University (ISU)

We have established a jointly funded faculty appointment in accelerator physics at ISU

- Jointly funded by JLab Accelerator Division and Idaho State University
- Based at the Idaho Accelerator Center

- Dr. Giulio Stancari was selected and has started at IAC
- Initial priority is the development of a 10 MeV positron source

Summary

- Accelerator Science is flourishing
  - Main problem is to stay focused
  - Need to cover principal bases until decision on next JLab accelerator project
- Accelerator R&D focused on all aspects of SRF Linacs
  - Best match to our expertise
  - Matched to future scientific options at JLab
    - ELIC/MEIC is good match
    - 4th Generation Light Source is a better match to our technology
- Funding comes from a variety of sources
  - Enables us to work on non-NP technology R&D

My concerns

- Budget has been extremely tight
  - External funding enables us to maintain our expertise
    - Easy to lose focus on primary goals
- Only ~2 FTE worked on ELIC for the last three years
  - BNL has ~9 FTE working on e-RHIC this year
    - We risk losing the project by not investing enough
- No mandate to design a large 4th Generation Light Source
  - We develop technology with other people's money
  - This will not enable us to make an informed decision on the next JLab accelerator in a reasonable time-frame