JLAB plans for SRF developments

Mircea Stirbet
Jefferson Laboratory

JLab Accelerator Science

- Our goal is to be the best in the world in 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 Electron-Ion Colliders and Energy Recovery Linacs)
  - FELs (George Neil)

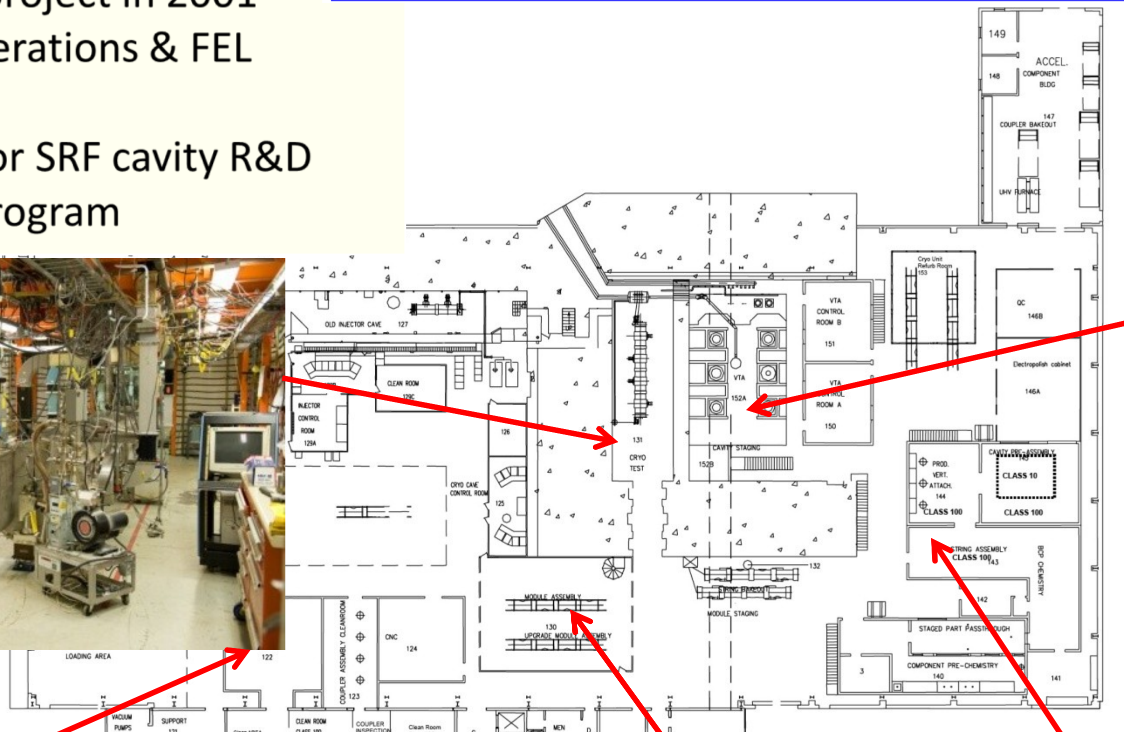
Jefferson Lab operates a kilowatt-class, high-average-power, sub-picosecond free-electron laser, covering the mid-infrared spectral region. On July 21, 2004, 10 kilowatts of cw operation was achieved at a wavelength of 6 microns. This was extended on Oct. 30, 2006 to 14.2 kilowatts of cw light at 1.6 microns. Extensions of the FEL to 250nm in the UV are planned. The short pulses of electrons also produce hundreds of watts of broadband THz light, which is made available in a special user laboratory. The laboratory also operates an ultraviolet free-electron laser which on August 31, 2010 lased in the spectral region down to 363 nm with 100W average power levels.

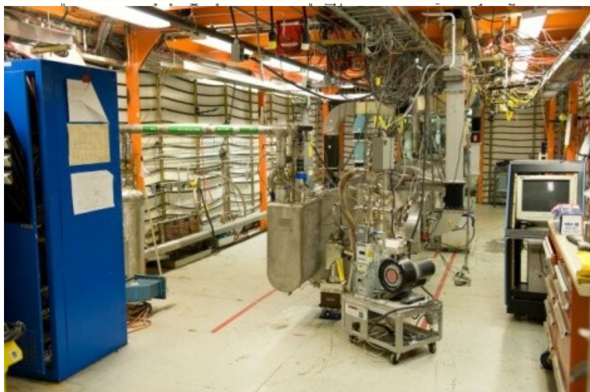
- Goals have been established for each R&D area which support the overall Accelerator Goals
- We collaborate on projects that profit from our core competencies
  - SNS, FRIB, Project X, ESS . . . . .
- Seeking collaboration on ADS
  - Waste transmutation
  - Accelerator-driven sub-critical reactors

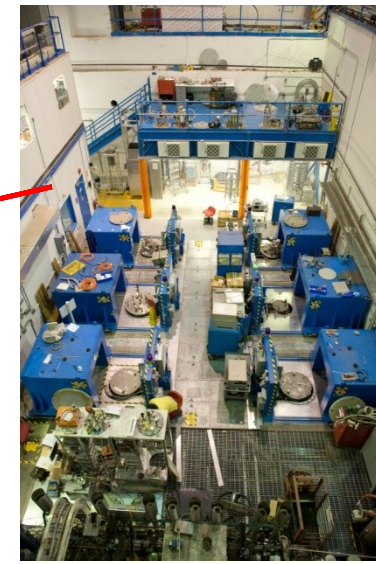
JLab Institute for Superconducting RF Science and Technology

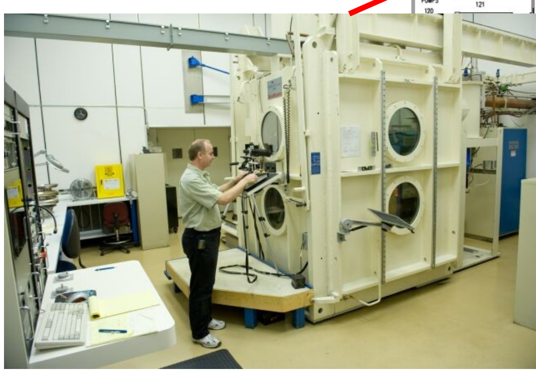
- Established for CEBAF construction
- Upgraded for SNS project in 2001
- Supports 6 GeV operations & FEL
- Ready for 12 GeV
- Leading US effort for SRF cavity R&D
- Active education program

Only place in the world with concept-to-delivery SRF capability









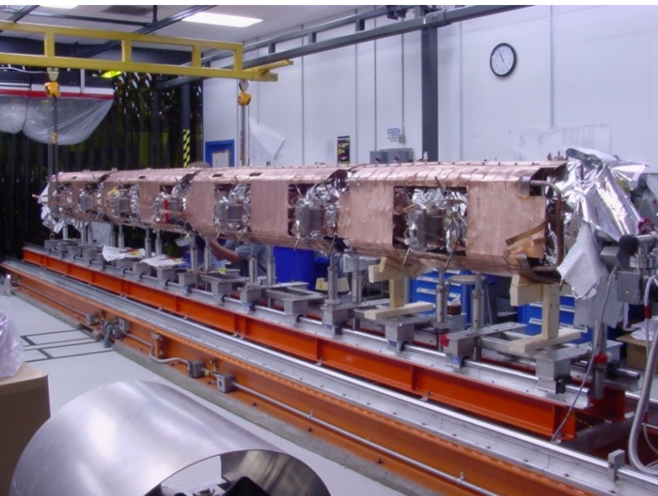
JLab SRF Experience

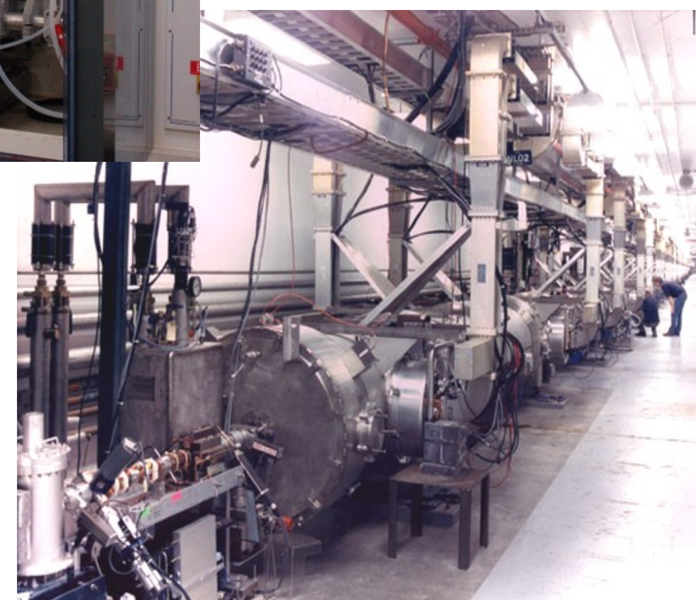
- The SRF Institute has fabricated and/or processed a wider variety of multi-cell SRF cavities than anyone else
- 87 cavities fabricated / >650 multi-cell cavities processed
  - 26 different cavity types processed
- In addition, a large number of smaller test cavities have been fabricated and/or processed for materials and processes R&D
- >3200 individual cryogenic cavity tests since 1991
- Assembled and delivered 82 completed cryomodules
  - 43 for CEBAF
  - 4 for JLab FEL
  - 23 for SNS @ ORNL
  - 2 for others
  - Refurbished 10 cryomodules for CEBAF

JLab Multicell Nb Cavity Experience

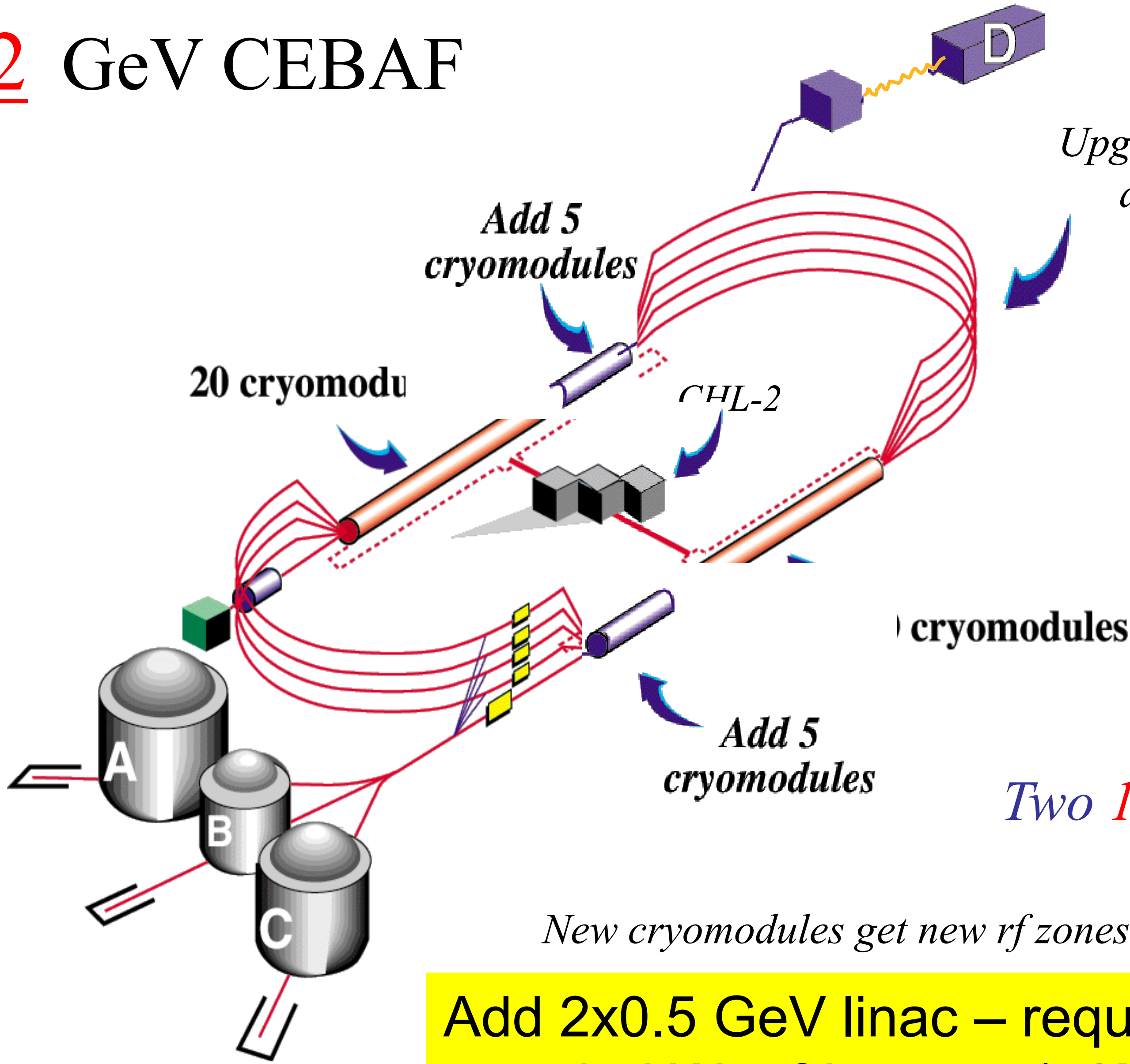
Project	# of Cavities built @ Jlab	# of Cavities processed / tested	Frequency (MHz)	Beta	# of Cells	Duty Factor
CEBAF (OC cell shape)	20	358	1497	1	5	CW
CEBAF (OC) - C50 rework		94	1497	1	5	CW
CEBAF Upgrade Style (OC)	8	8	1497	1	7	CW
CEBAF Upgrade Style (LL)	5	5	1497	1	7	CW
CEBAF Upgrade Style (HG)	9	11	1497	1	7	CW
C100 - (LL)	4	4	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	1	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	47	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
Rossendorf - Inj	2		1300	1	2.5	CW
PKU 3.5 cell Inj		1	1300	1	3.5	CW
ILC - (TESLA)		22	1300	1	9	Pulsed
ILC - (LL)	1	1	1300	1	7	Pulsed
ILC - (Japan LL)		2	1300	1	9	Pulsed
ILC - (TESLA)	4	4	1300	1	9	Pulsed

SRF Photo gallery





12 GeV CEBAF

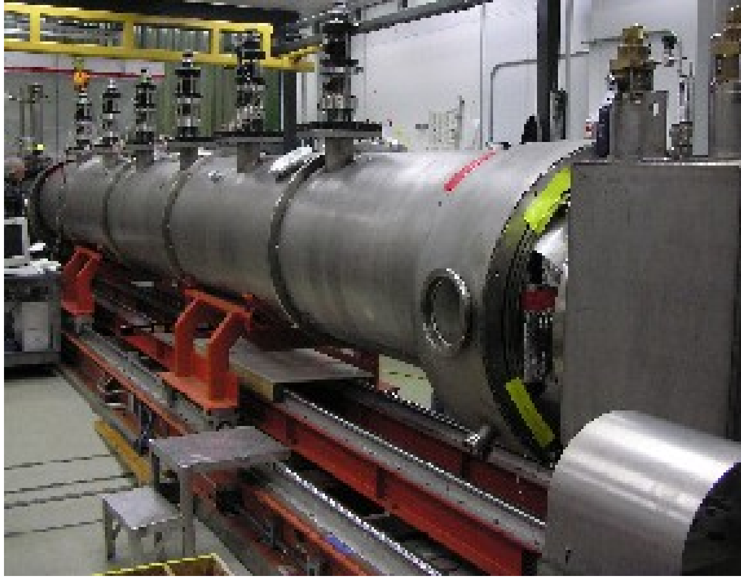


Two 1.1 GV linacs

New cryomodules get new rf zones

Add 2x0.5 GeV linac – requires new 4.5kW refrigerator (~6MW)

CEBAF Upgrade Cryomodule

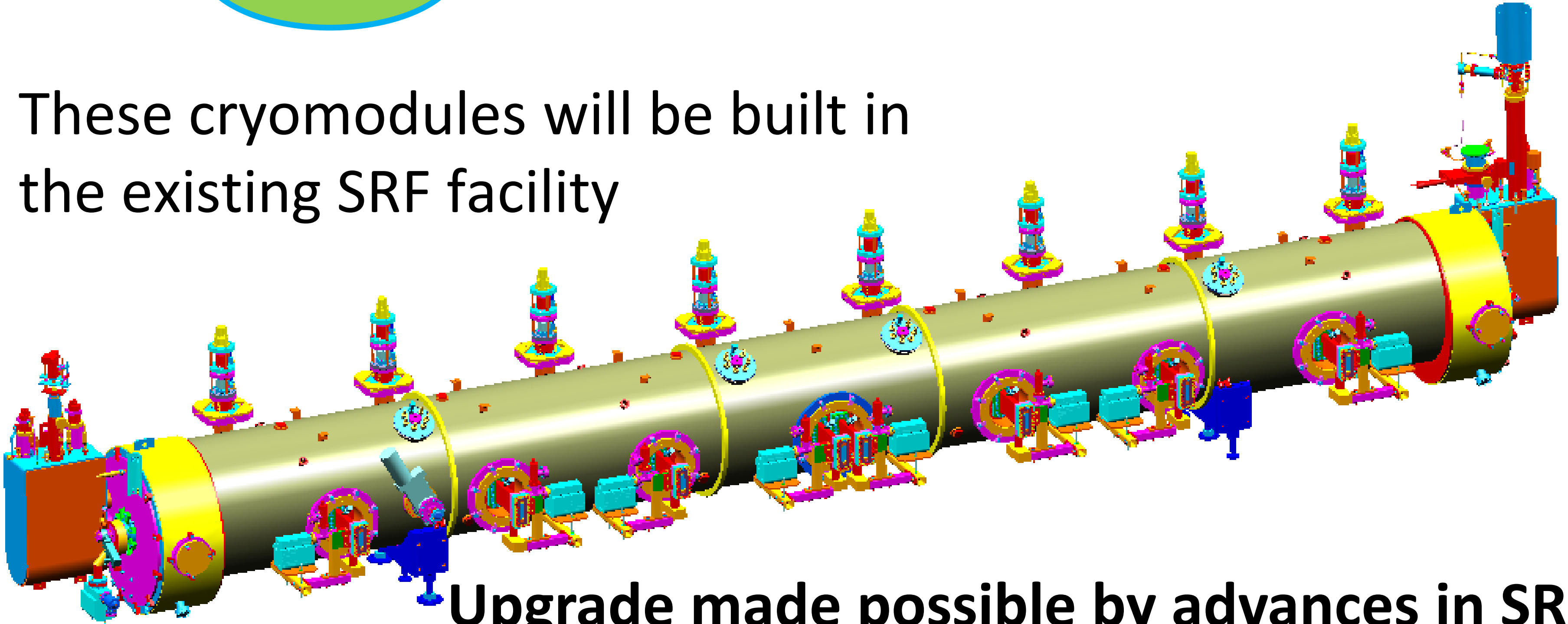


108 MV, 20 MV/m, 7-cell cavities

Compare with original CEBAF cryomodule specification

20 MV, 5-cell cavities

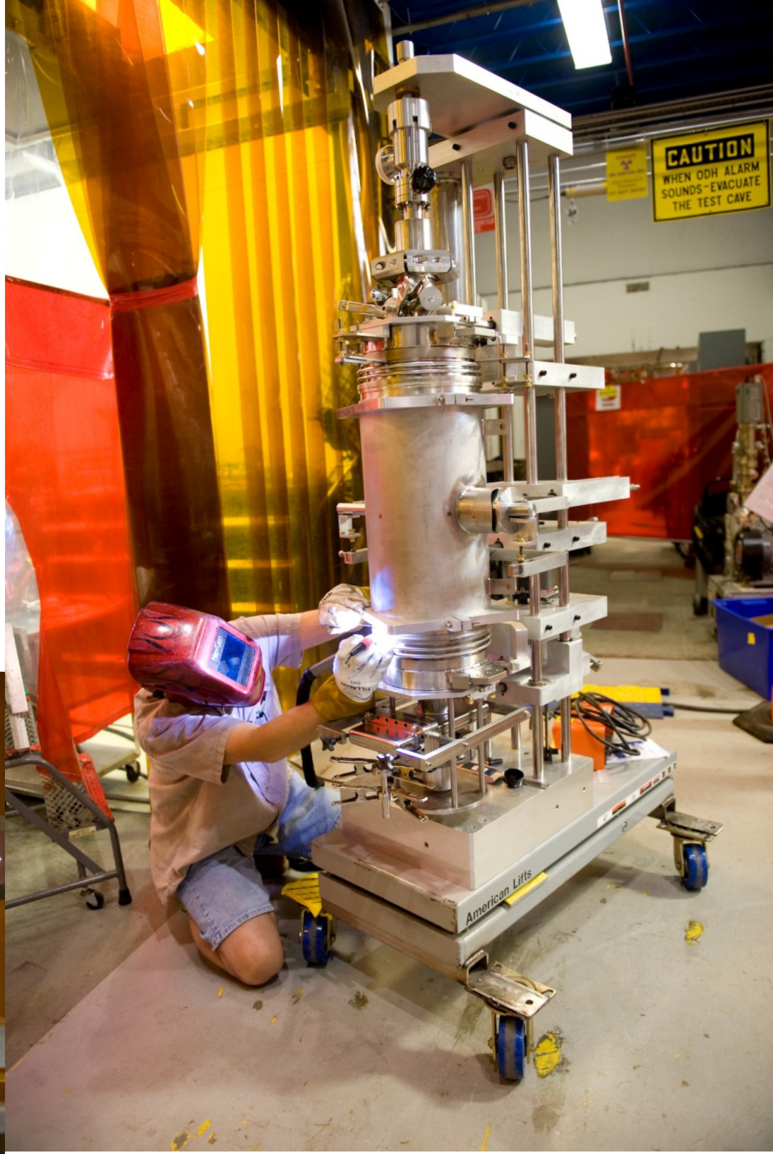
These cryomodules will be built in the existing SRF facility



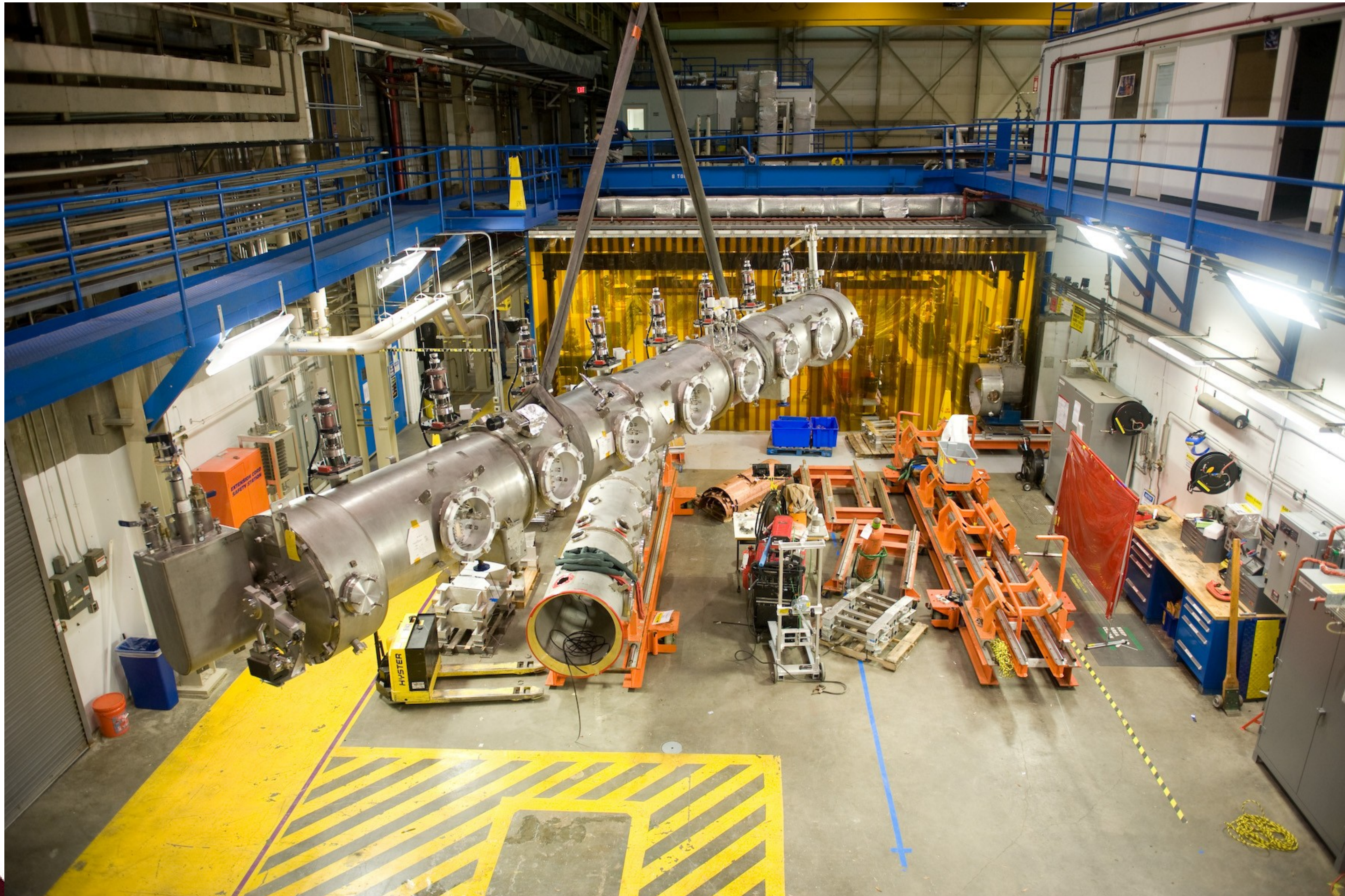
Upgrade made possible by advances in SRF

Prototype C100

- Testing welding jig for 12 GeV Upgrade Helium vessel
  - Found problem with magnetization of Helium vessel
  - Have re-ordering parts to maintain high Q



Prototype C100 Cryomodule



R&D to Increase the Gradient

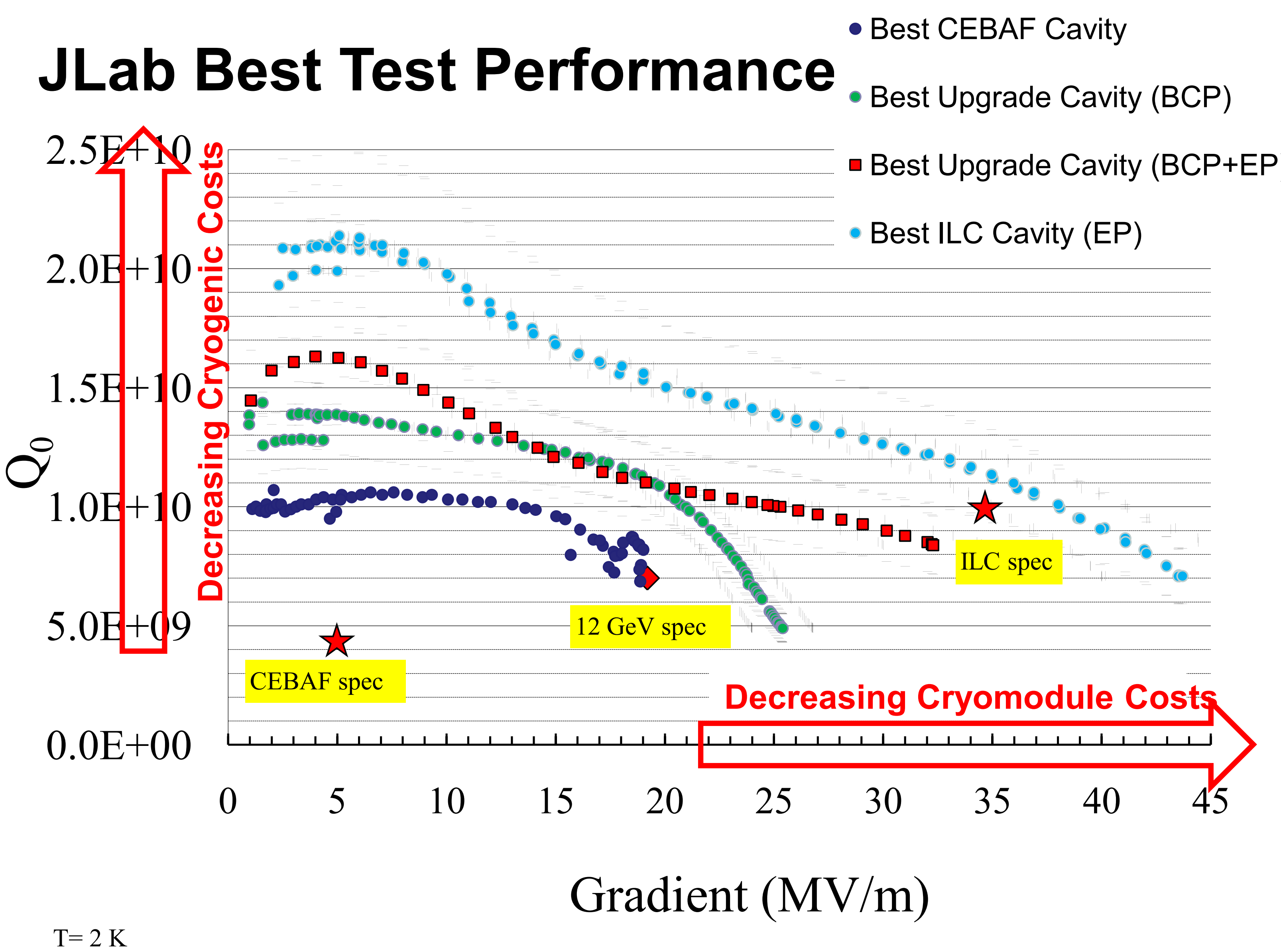
- Higher gradients reduce cost of tunnel and equipment
- Challenges are to push gradient to fundamental material limits, narrow the spread in performance and eliminate early failures due to material or fabrication defects or contamination
- International Linear Collider (ILC) has funded an R&D program to increase this performance
  - JLab provides most of the cavity data for the Americas region
    - Improved cleaning and assembly practices
    - Electro-polishing process optimization
    - Developing next generation processing equipment
- Results are being applied to all superconducting cavities

The path towards higher Q_0

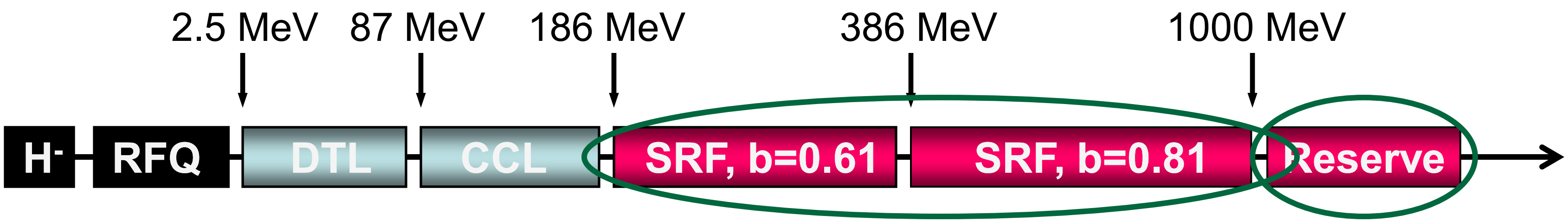
- **Present day**
  - **Trained personnel for cleanroom activities**
  - **Follow established cleaning and HWP rinsing procedures to eliminate field emission**
  - **Controlled chemistry: BCP and EP**
  - **Cavity firing (high temperature) and bake (low temperature) under vacuum.**

- **Short-term:**
  - **Fully exploit the superconducting properties of bulk Niobium for operation at $\leq$ 2 K**
- **Long-term:**
  - **Develop new superconducting materials for RF applications and operation at 4.5 K**

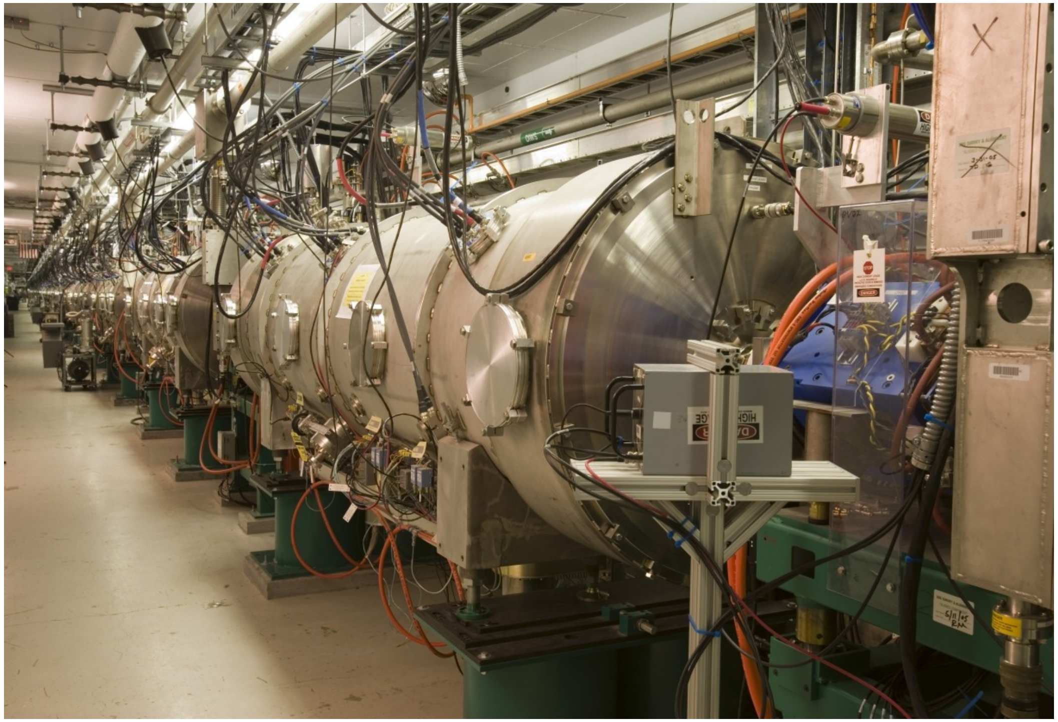
JLab Best Test Performance



SNS Linear Accelerator



- World's first high-energy superconducting linac for protons
- 81 independently-powered 805 MHz SC cavities, in 23 cryomodules
- Space is reserved for additional cryomodules to give 1.3 GeV
  - Power Upgrade Project - PUP

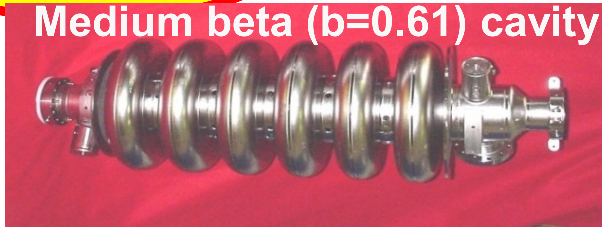


As of September 2009 a sustainable 1 MW in beam power was achieved at Oak Ridge, continuing to make SNS the highest energy-pulsed neutron source available for scientific research worldwide.

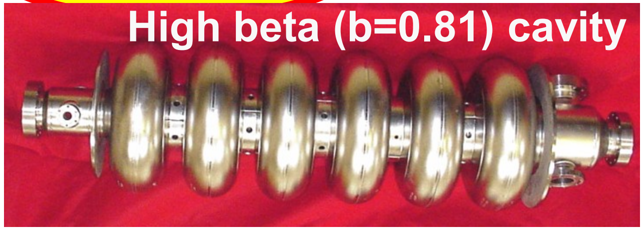
Courtesy Stuart Henderson

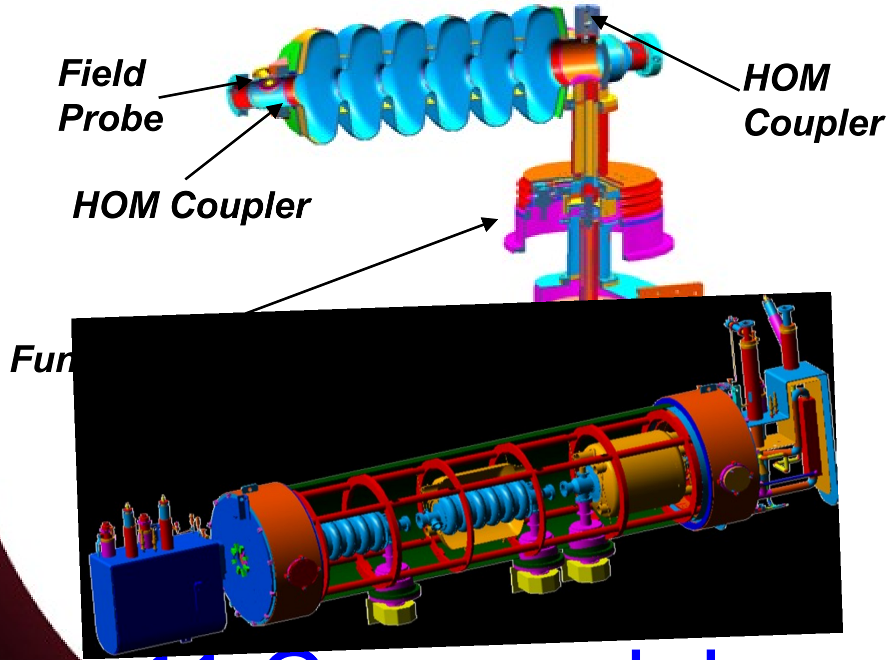
SNS Cavities and Cryomodules

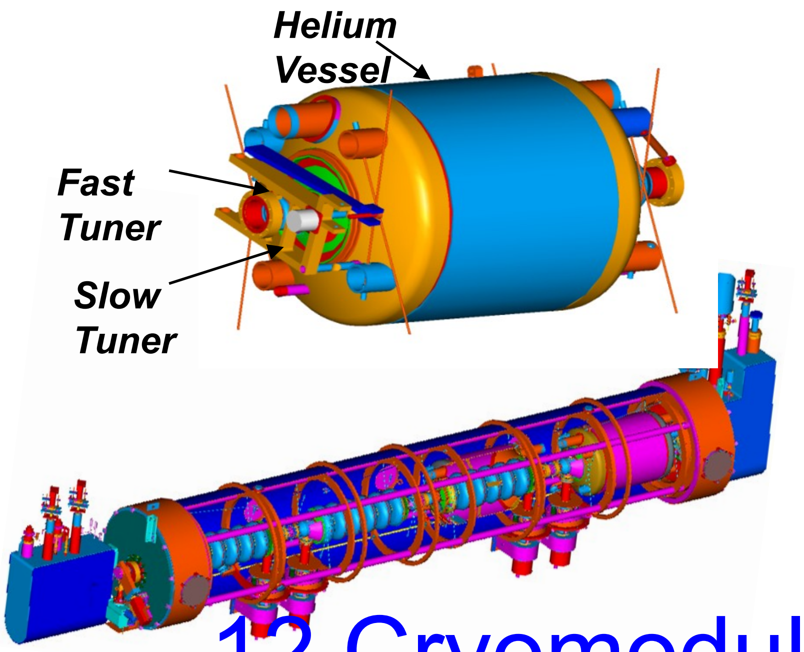
β=0.61 Specifications:
E_a=10.1 MV/m, Q_o> 5E9 at 2.1 K



β=0.81 Specifications:
E_a=15.8 MV/m, Q_o> 5E9 at 2.1 K





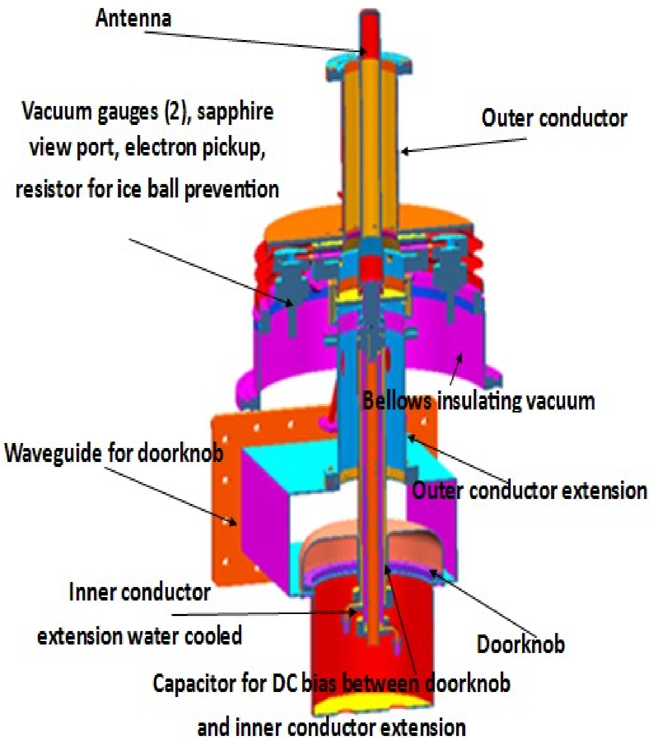


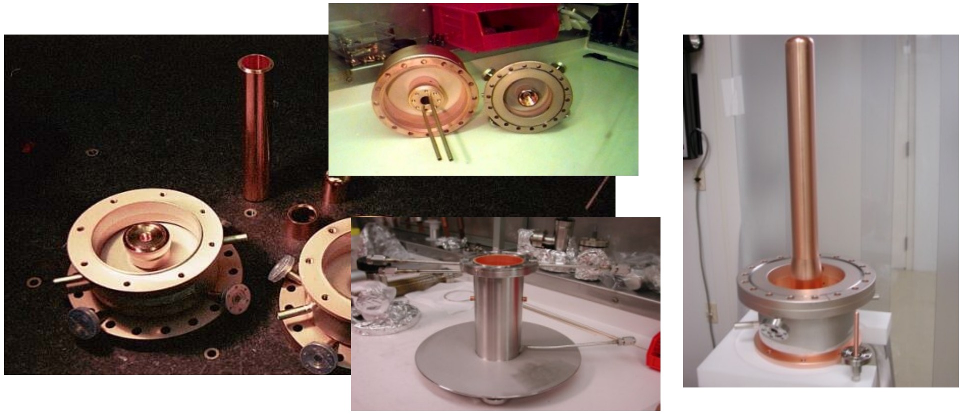
11 Cryomodules

12 Cryomodules

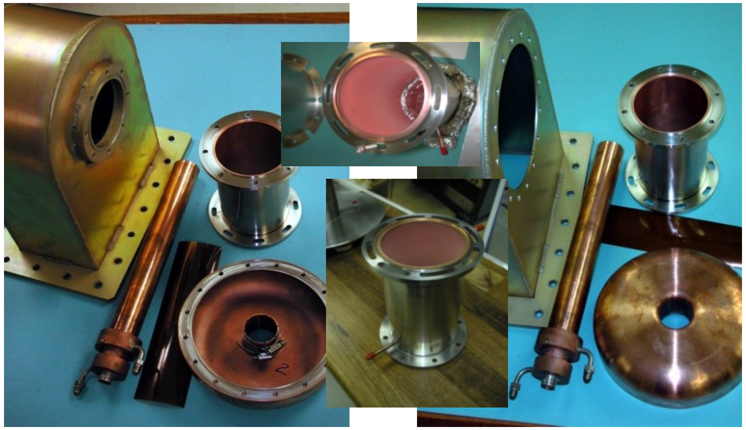
Low Beta cavities have lower gradient

Fundamental power couplers for SNS





Vacuum side components

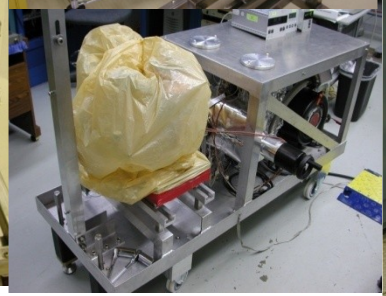
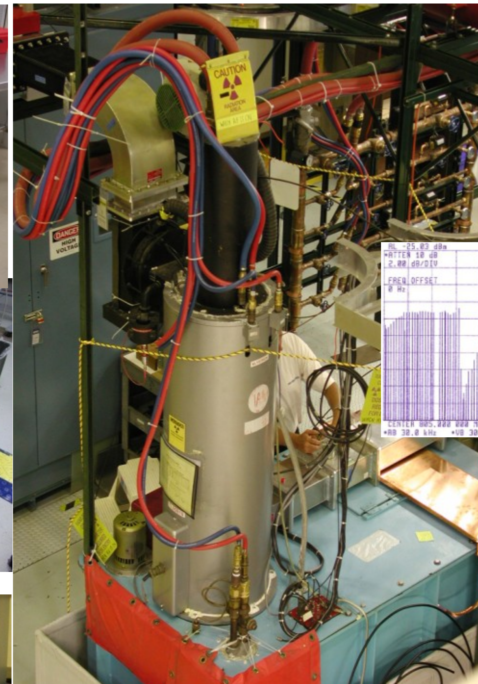
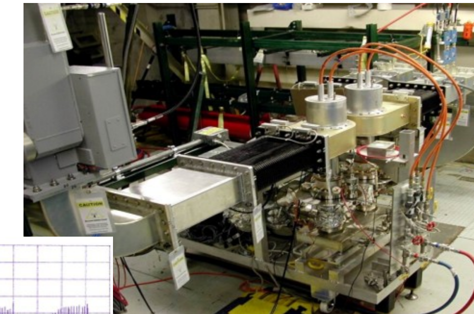
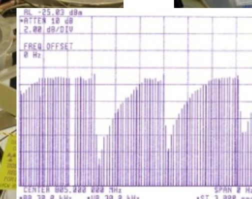
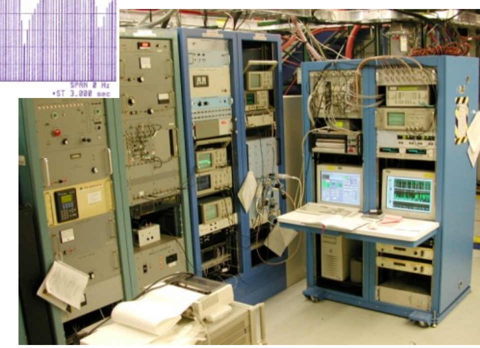
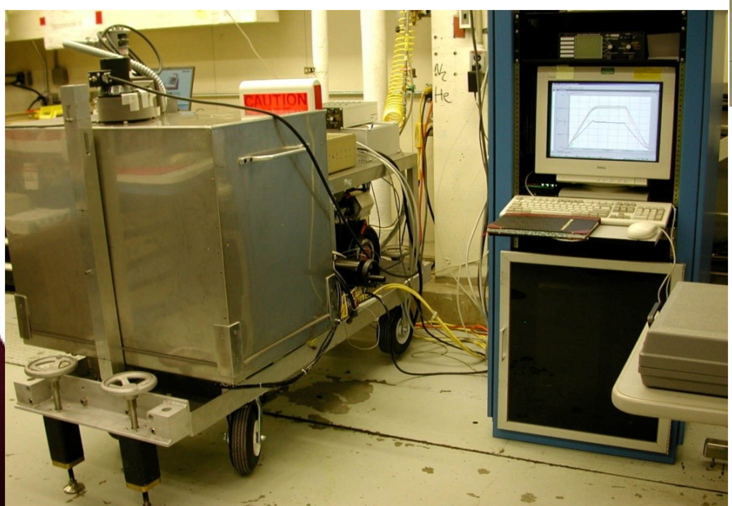


Air side components

A total of 81 sets (33 FPCs for Medium Beta cavities and 48 FPCs for High Beta cavities)
Frequency; 805 MHz, Impedance 50 Ohm
Operation mode: pulsed, 1.3 ms, 60 Hz
Peak pulse: 550 kW,
Average power: up to 53 kW

Qualifying power couplers

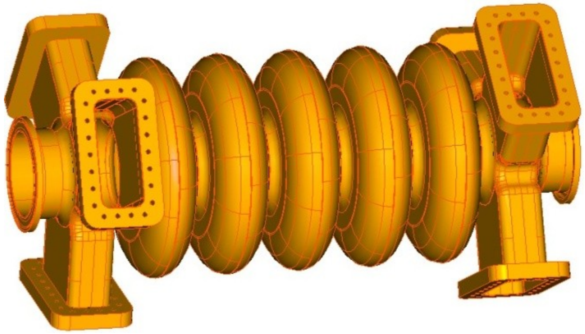


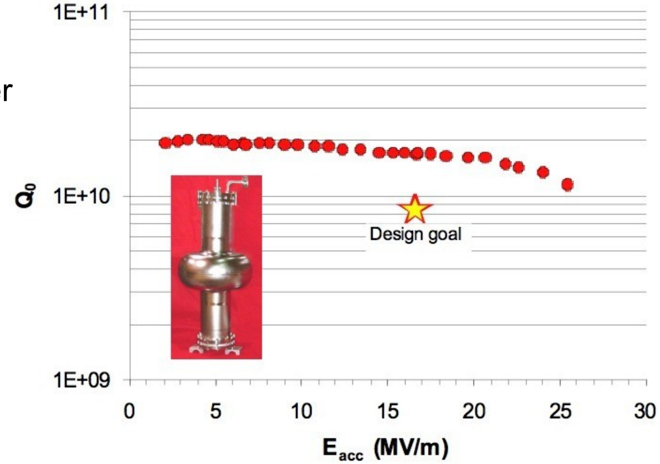
Complex sequence of procedures involving team work and dedicated tools for: incoming inspection , components cleaning and clean room assemble, vacuum leak checks, bake, qualification on room temperature RF test stand, storage , clean room assemble on cavity, RF conditioning and power tests during cryomodule commissioning.

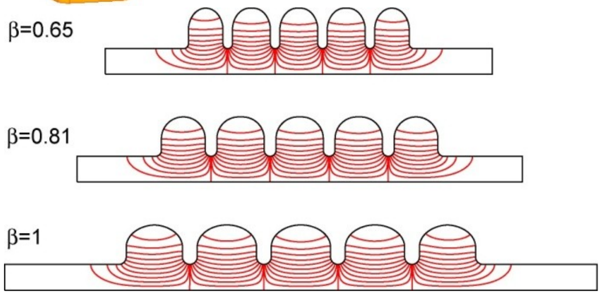
JLab High-Current Cavity

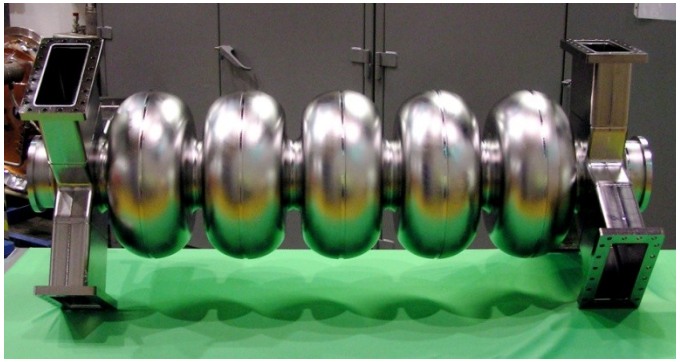
- Development of electron cavity for ≥100 mA

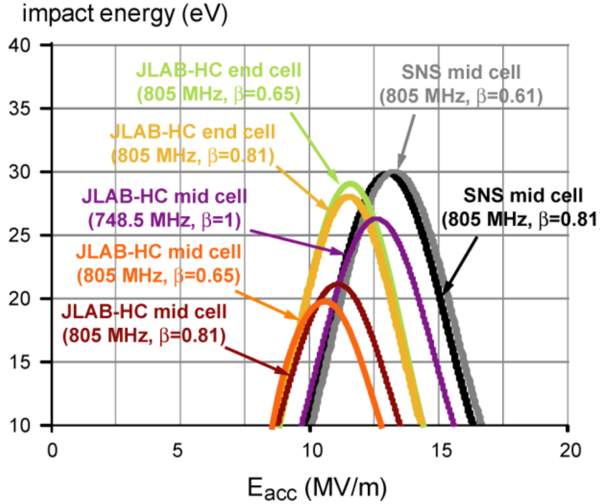


F. Marhauser
PAC09



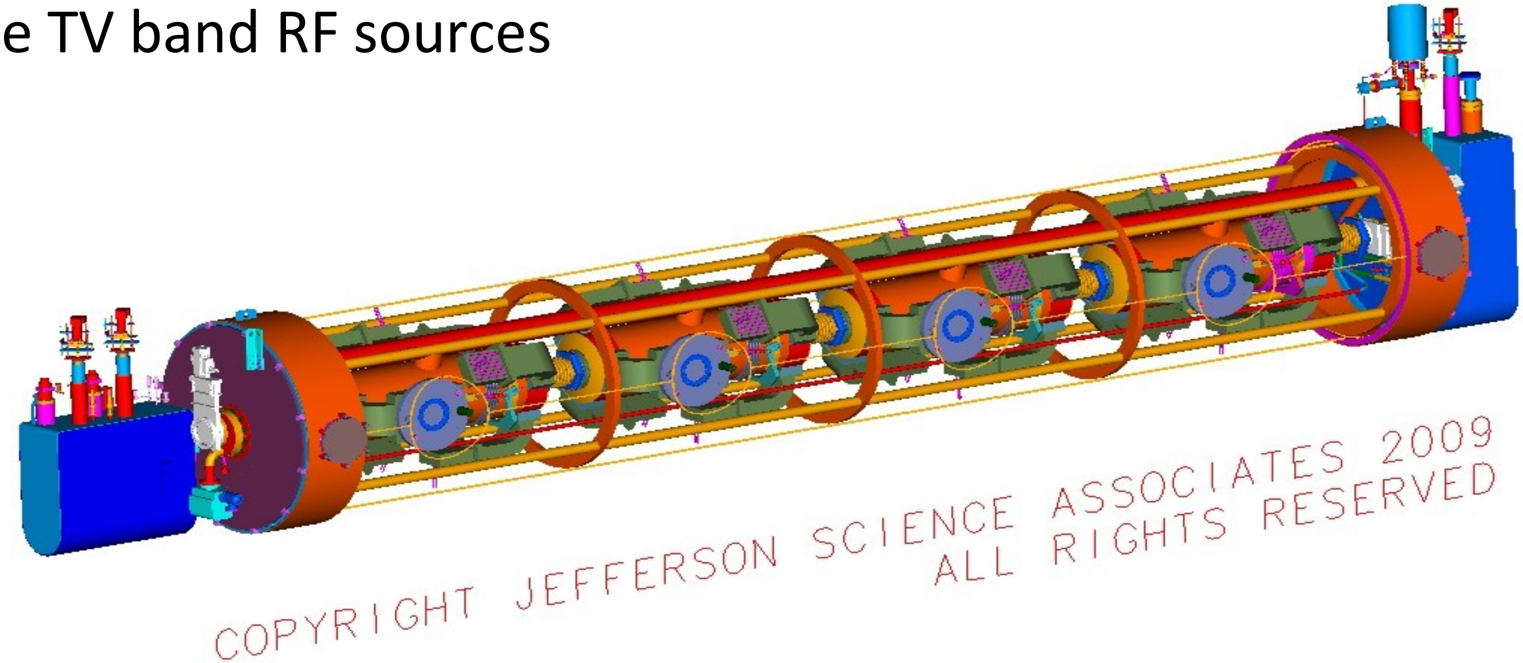




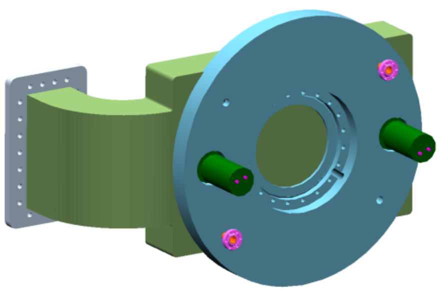


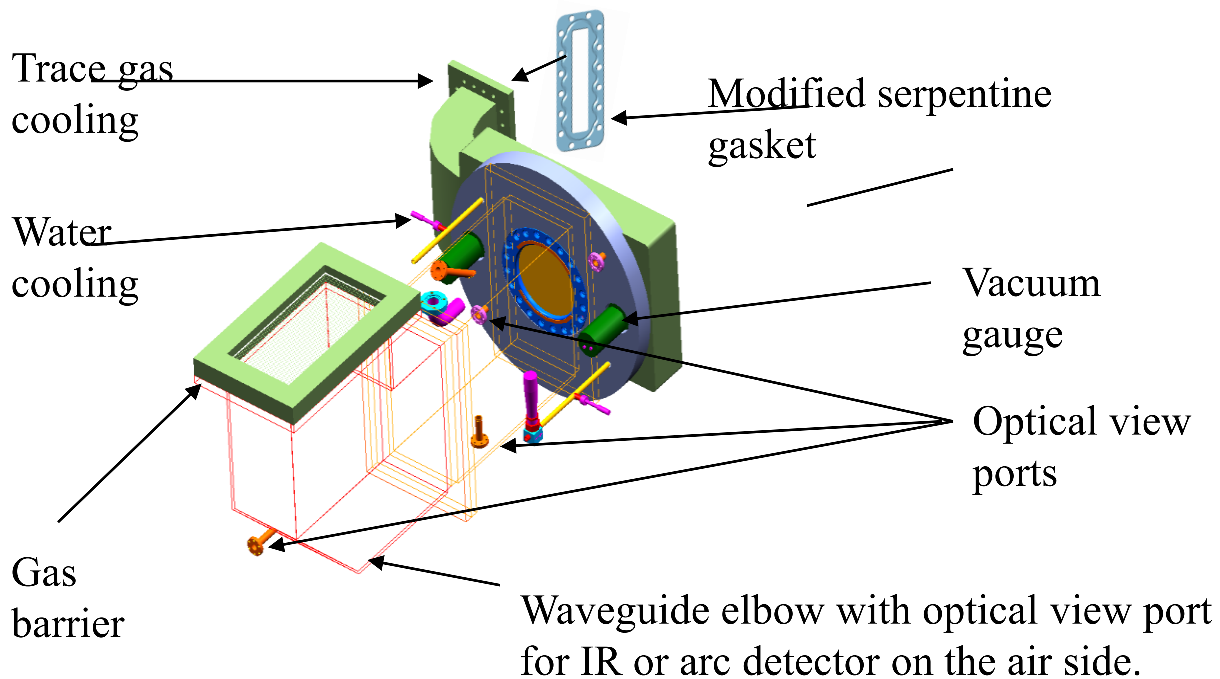
JLab High Current Cryomodule

- JLab 700 MHz ERL module (based on modified SNS layout)
- Could be economical if it can operate in BCS dominated regime
- Very large apertures (halo!)
- Very high BBU threshold
- Use TV band RF sources



JLab High Current Cryomodule - WFPC

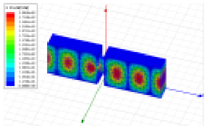


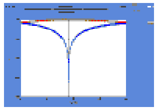


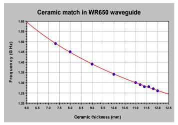
An WR1150 elbow with optical view port, followed by a gas barrier and WR1150 bellows will be used to connect the WFPC to the klystron. Two directional couplers will provide the FWD and RFL RF signals.

WR650 pre-compressed ceramic window for 1.3 and 1.5 GHz WFPC

Design and manufacture of the pre-compressed window







HFSS simulations

Ceramic thickness (mm)		Matching freq (GHz)			S11 (dB)	
Shimmed GAP	HFSS simulations	TRL no DELAY	TRL DELAY	HFSS simulations	TRL no DELAY	TRL DELAY
6.02	1.618	1.614	1.6159375	-73.38	-38.3	-52.36
7.26	1.518	1.518125	1.5184375	-68.83	-41.15	-37.34
8.01	1.47	1.472	1.471875	-65.44	-54.9	-43.6
12.01	1.28	1.279375	1.2796875	-63.74	-44.3	-47.8

Ceramic dimensions

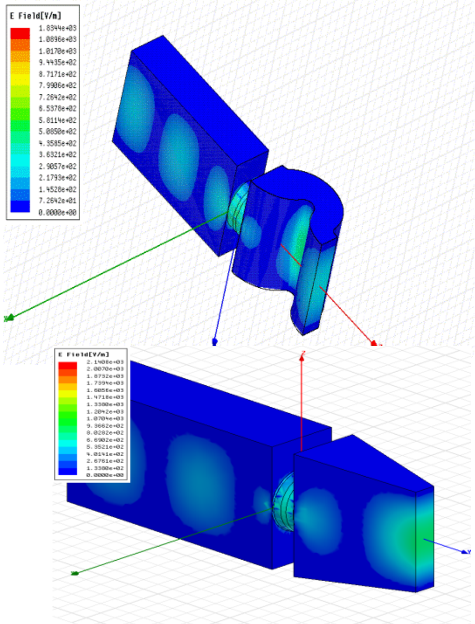
1.497GHz->7.57021mm

1.3 GHz->11.4922mm

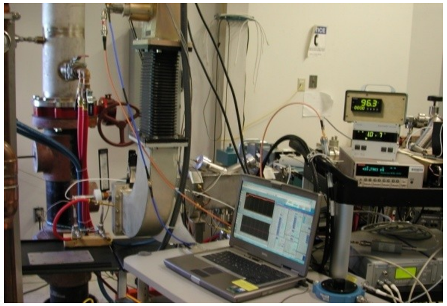
Setup for TRL measurements

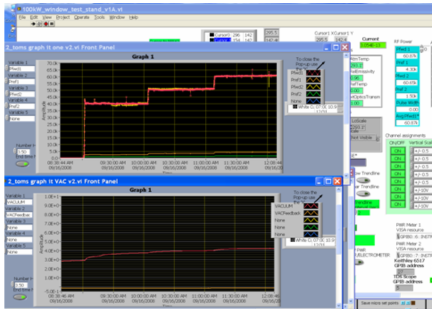
Vacuum furnace and sputtering systems

Proposals for WFPC



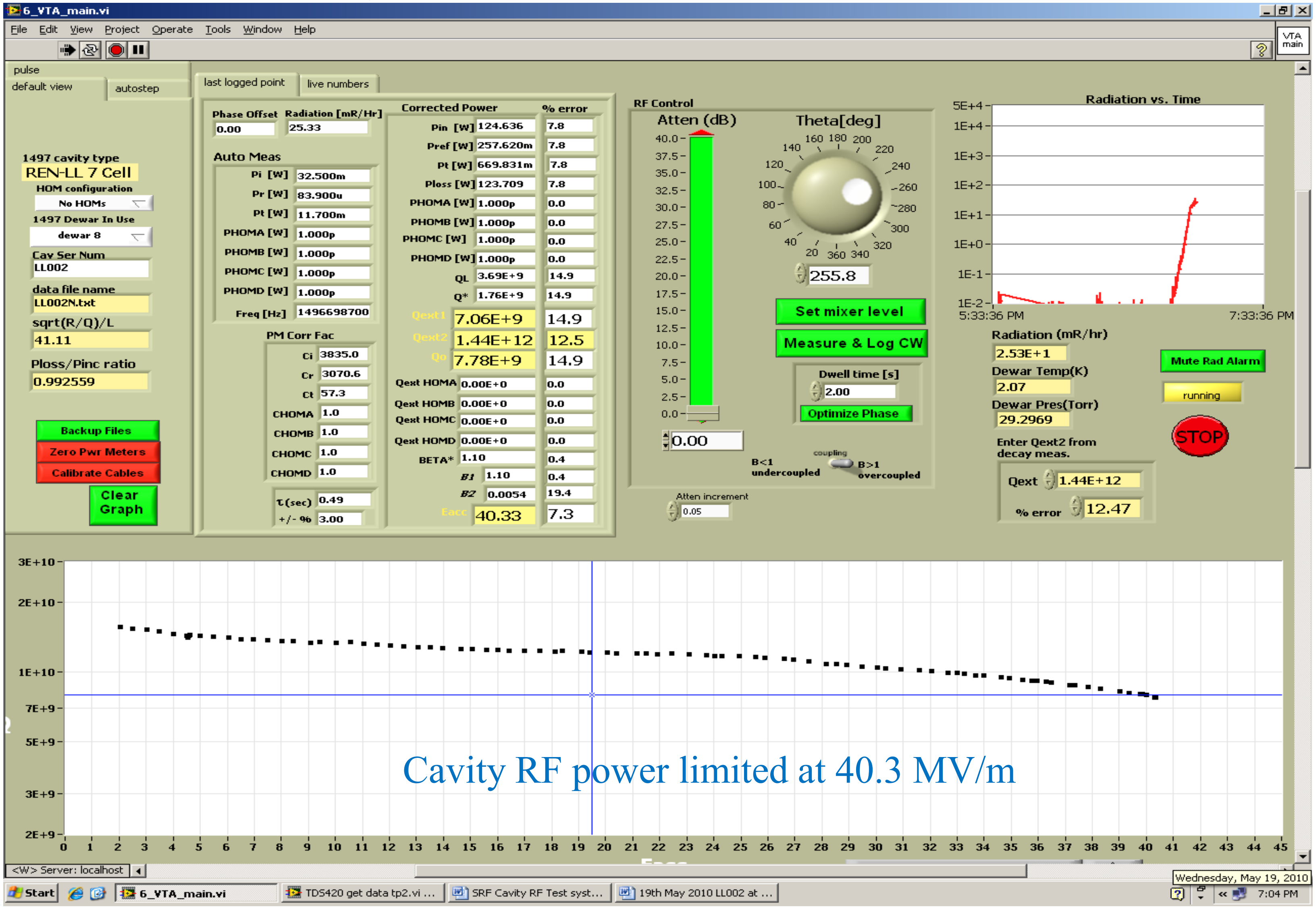
Power qualification of WR650 pre-compressed RF window





No vacuum activity at different RF power levels (1 hour in TW mode at 40, 50 and 60 kW CW). After 1 hour in TW mode at 60 kW temperature measured on the CDB window (no cooling) was106°C and on the brazed window (cooled with 2gpm) 82°C.

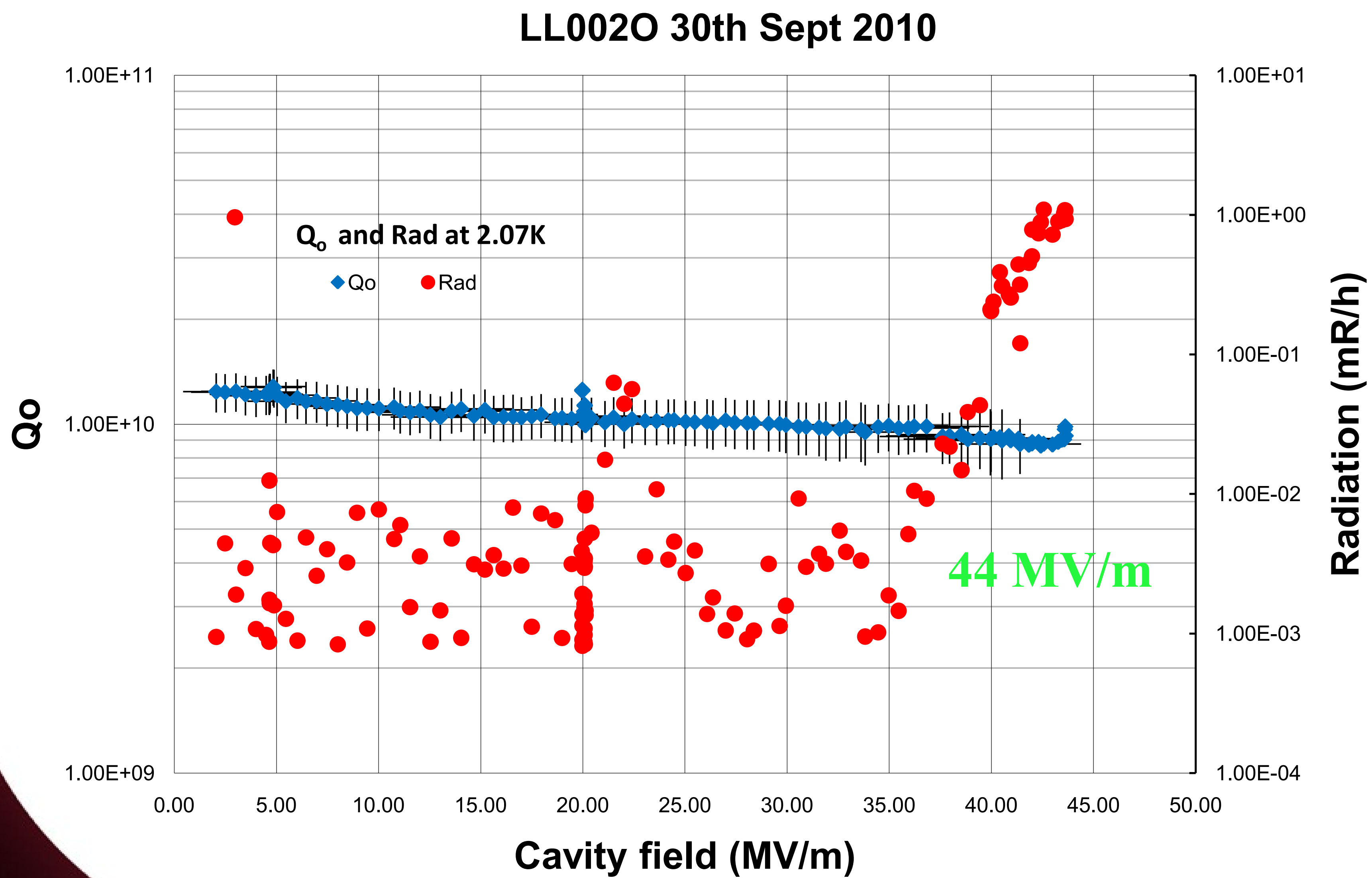
Cavity qualification in VTA



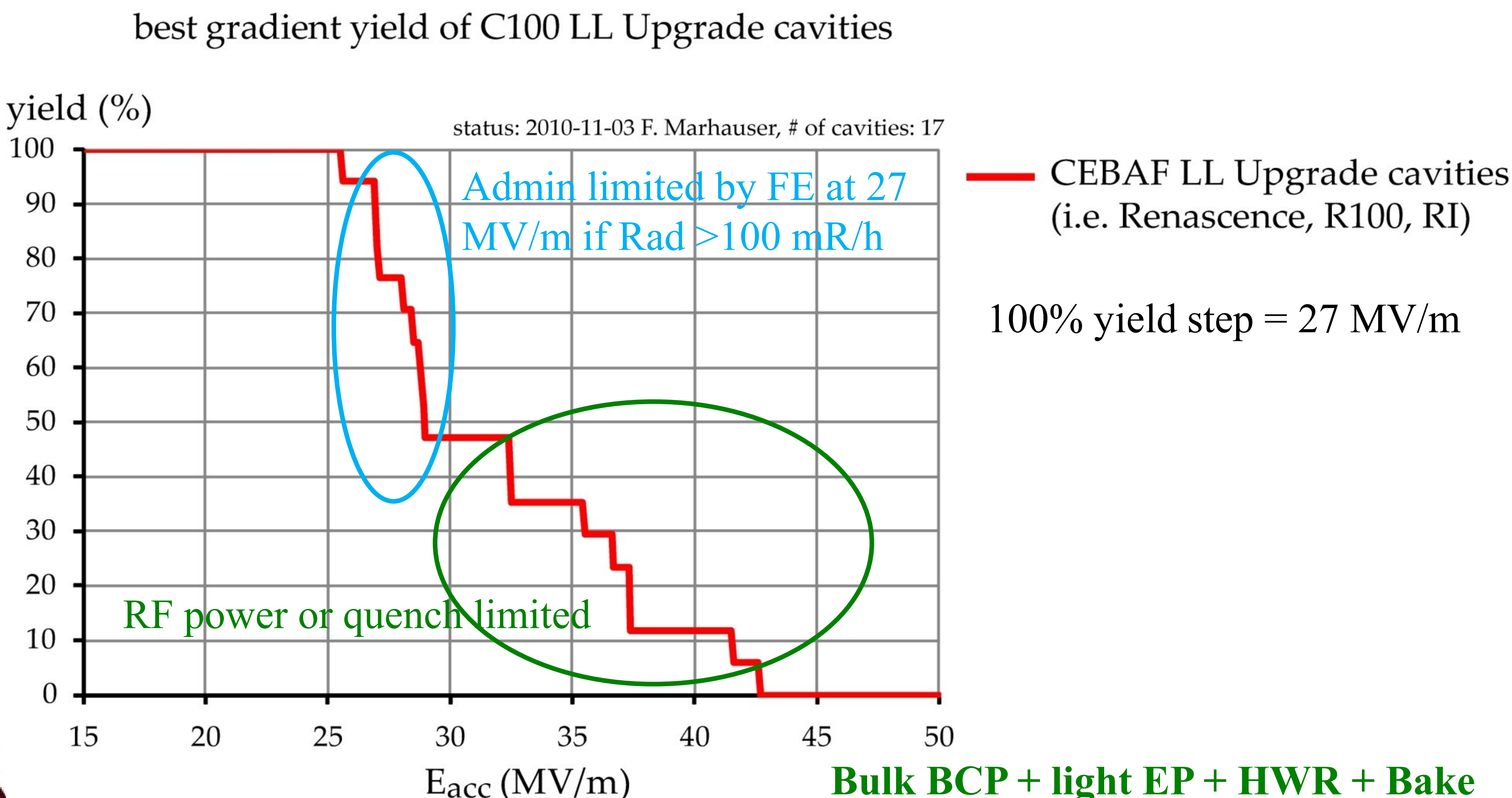
Cavity RF power limited at 40.3 MV/m

Jefferson Lab

Cavity qualification in VTA



JLab 7-cell yield for 12 GeV upgrade

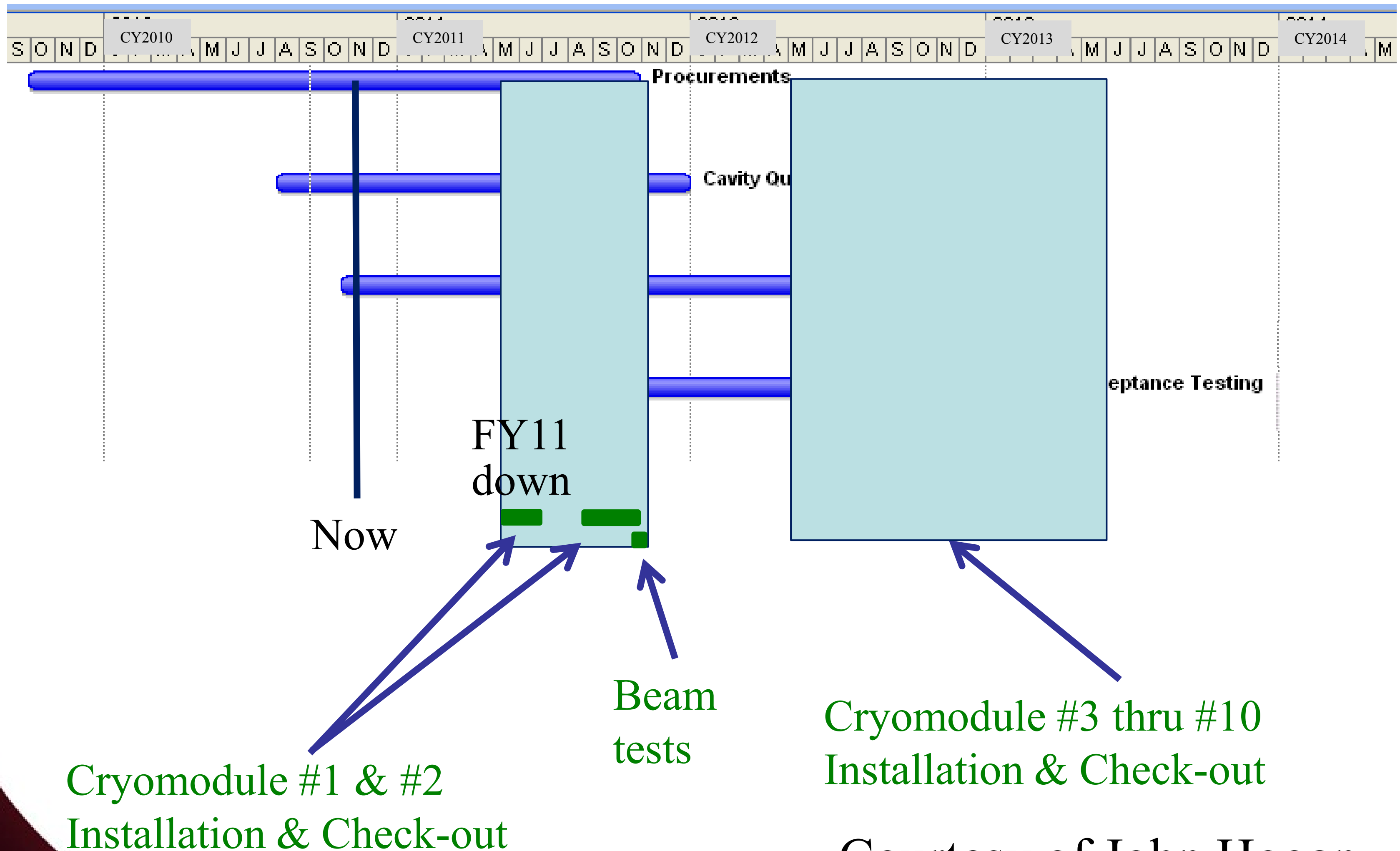


100% yield step = 27 MV/m

Bulk BCP + light EP + HWR + Bake

Courtesy of Frank Marhauser

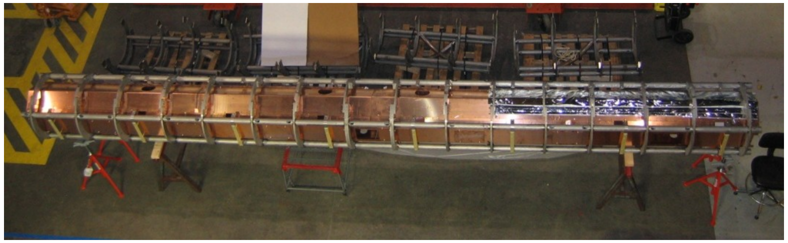
12 GeV Cryomodule Schedule (High Level)



Courtesy of John Hogan

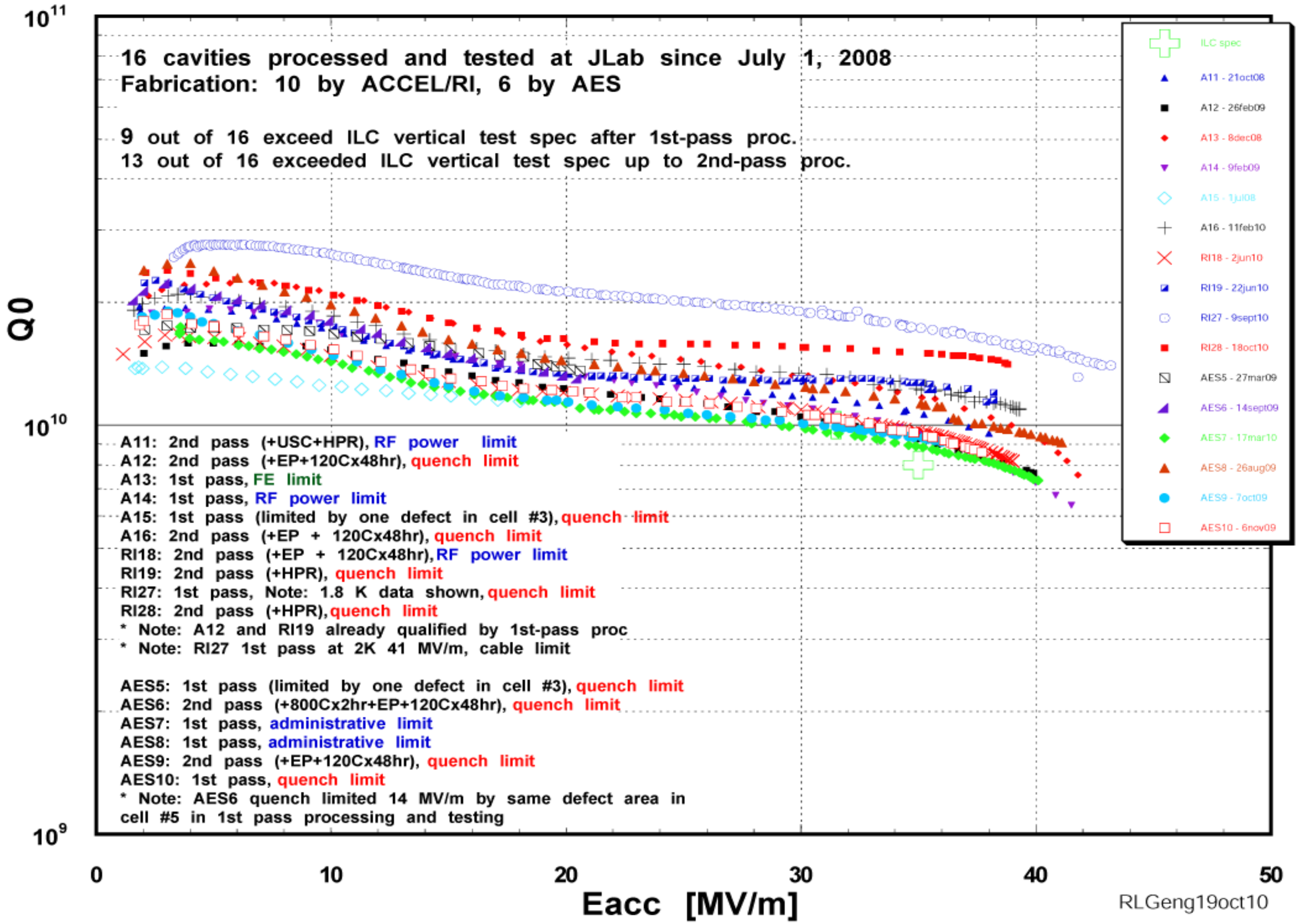
12 GeV Cryomodule Procurement & Assembly

- Cryomodule Procurement Status
  - Cavities: 46/86 received
  - Waveguides: 44/88 received
  - Helium Vessels: 16/90 received
  - Space Frames: First article received
  - Tuners:
    - Cold Complete
    - Warm - First Article due November
  - Helium Headers: Complete
  - Thermal Shield: 6/10 received
  - Magnetic Shield:
    - Cold – 4/10 Received
    - Warm – First article due November
  - Vacuum Vessel 3/10 received
  - End Cans 3/10 received
- Cryomodule Assembly
  - First cavity-string due December 2010



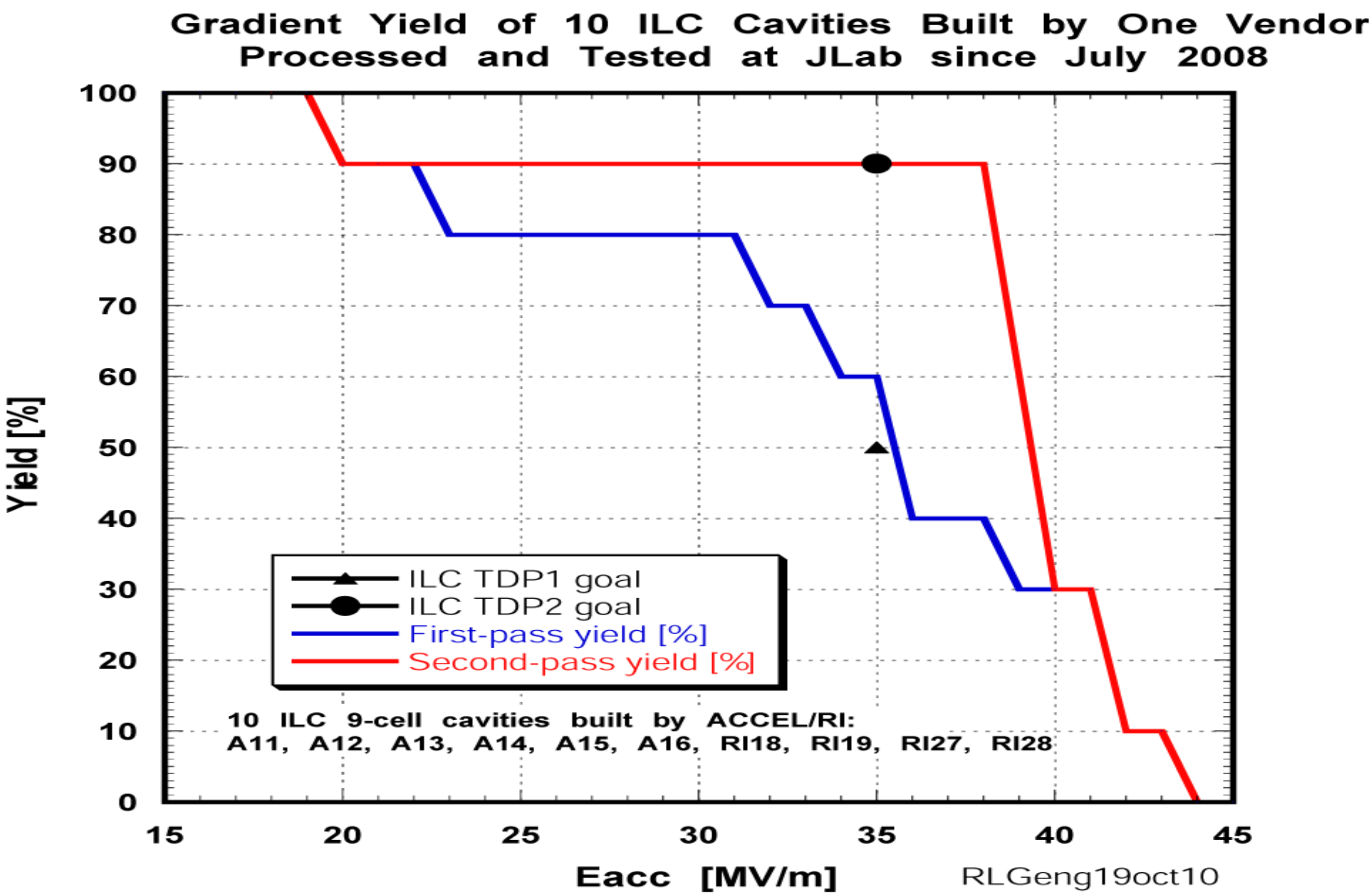
Courtesy of John Hogan

ILC activities at JLab



Courtesy of Rongli Geng

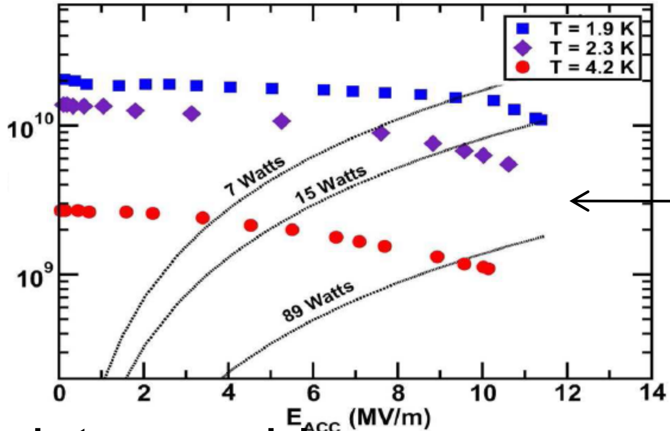
An example of 90% yield at 35 MV/m w/ Q0 >= 8E9 ACCEL/RI cavities without bias



Courtesy of Rongli Geng

Superconducting Low Beta Structures

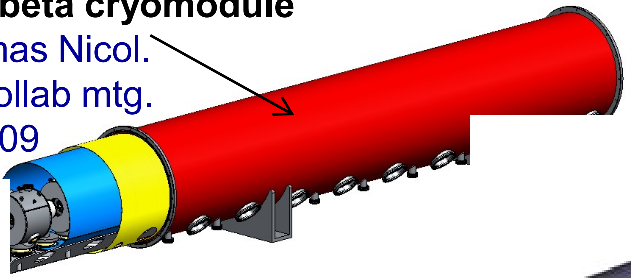
SSR1



ANL TSR

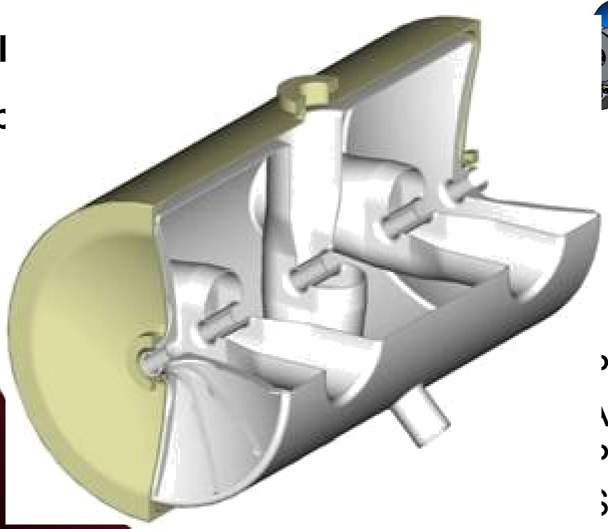
Low beta cryomodule

Thomas Nicol.
PX collab mtg.
9-11-09

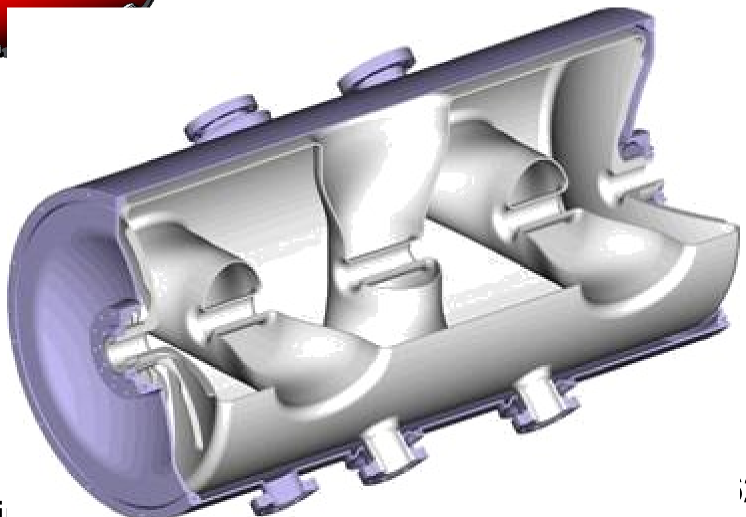


ANl

Trip



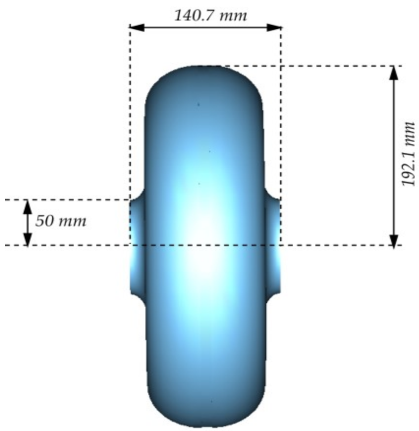
'.N. Ostroumov
\NL Physics Division
'roject X collaboration meeti..g
;eptember 11, 2009

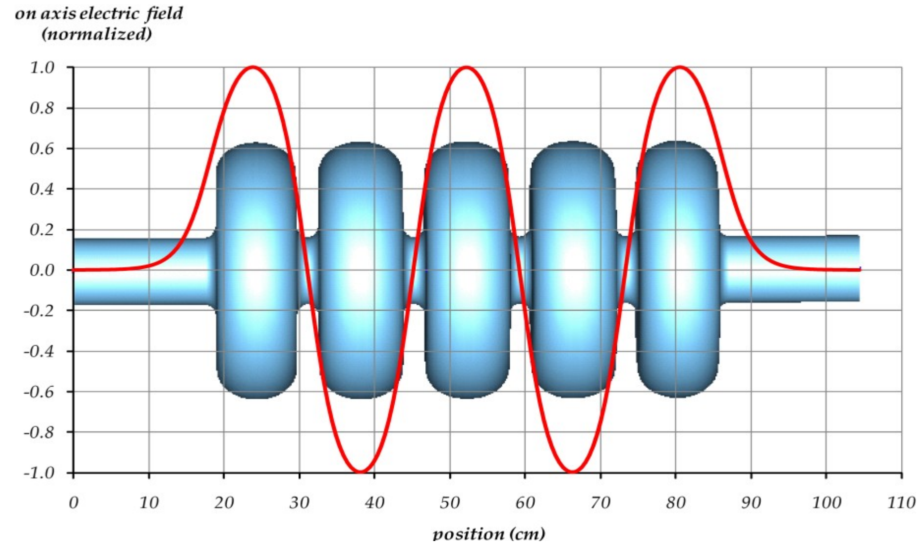


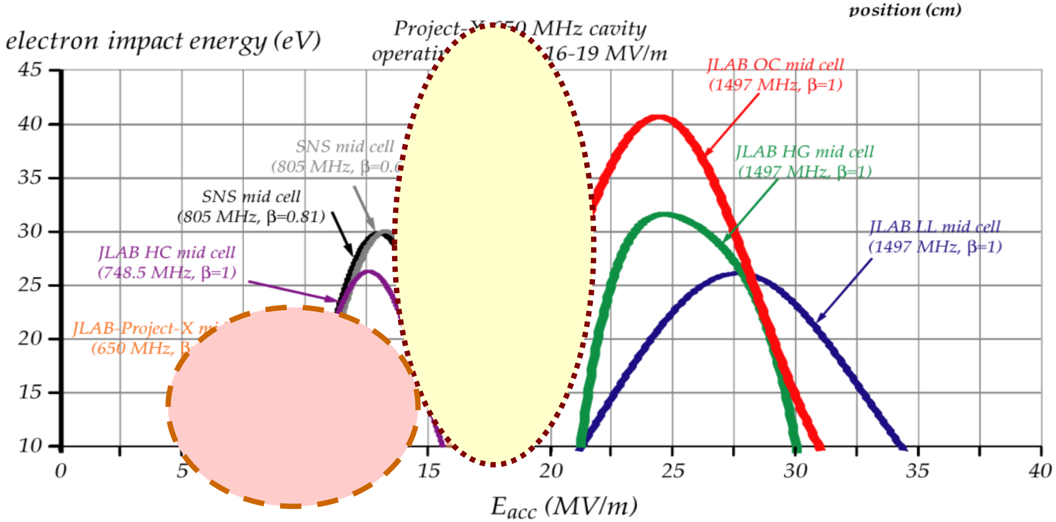
2

Triple-spoke

650 MHz Medium beta (β = 0.61) cavity design for Project-X







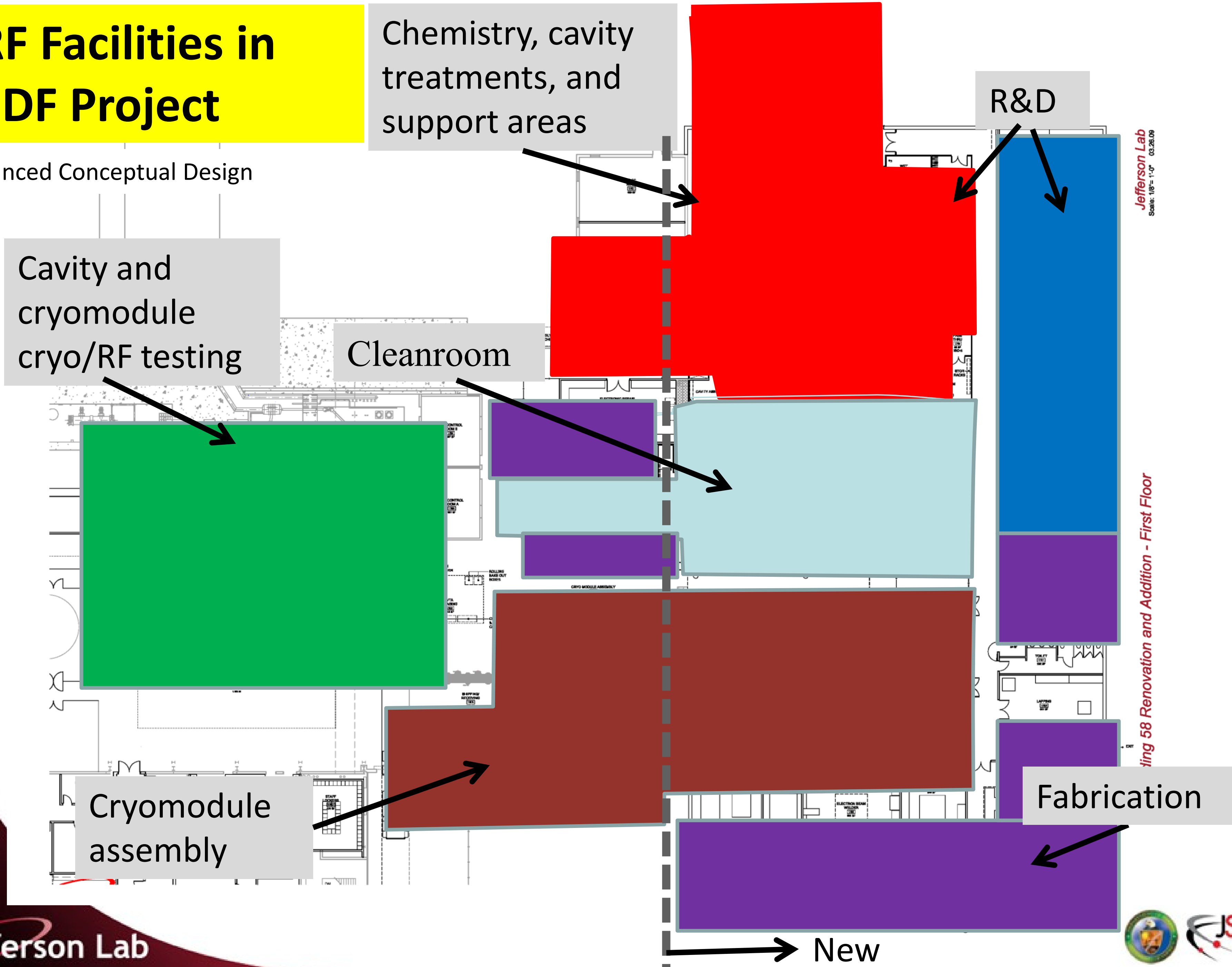
Cavity shape optimized for a operating gradient of 16-19 MV/m and minimal multipacting.

Courtesy of Frank Marhauser

reference: JLAB-TN-10-043

SRF Facilities in TEDF Project

Advanced Conceptual Design



Test Lab Renovation Has Started

TEDF – Technology and Engineering Development Facility

- We have developed a business plan based on restoring original CEBAF SRF capacity – 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 and should be available in 2013.

Test Lab (refurbished)


Thank you!