Production and Performance of SRF Cavities for the CEBAF 12 GeV Upgrade and JLab SRF Facilities Upgrade Plans

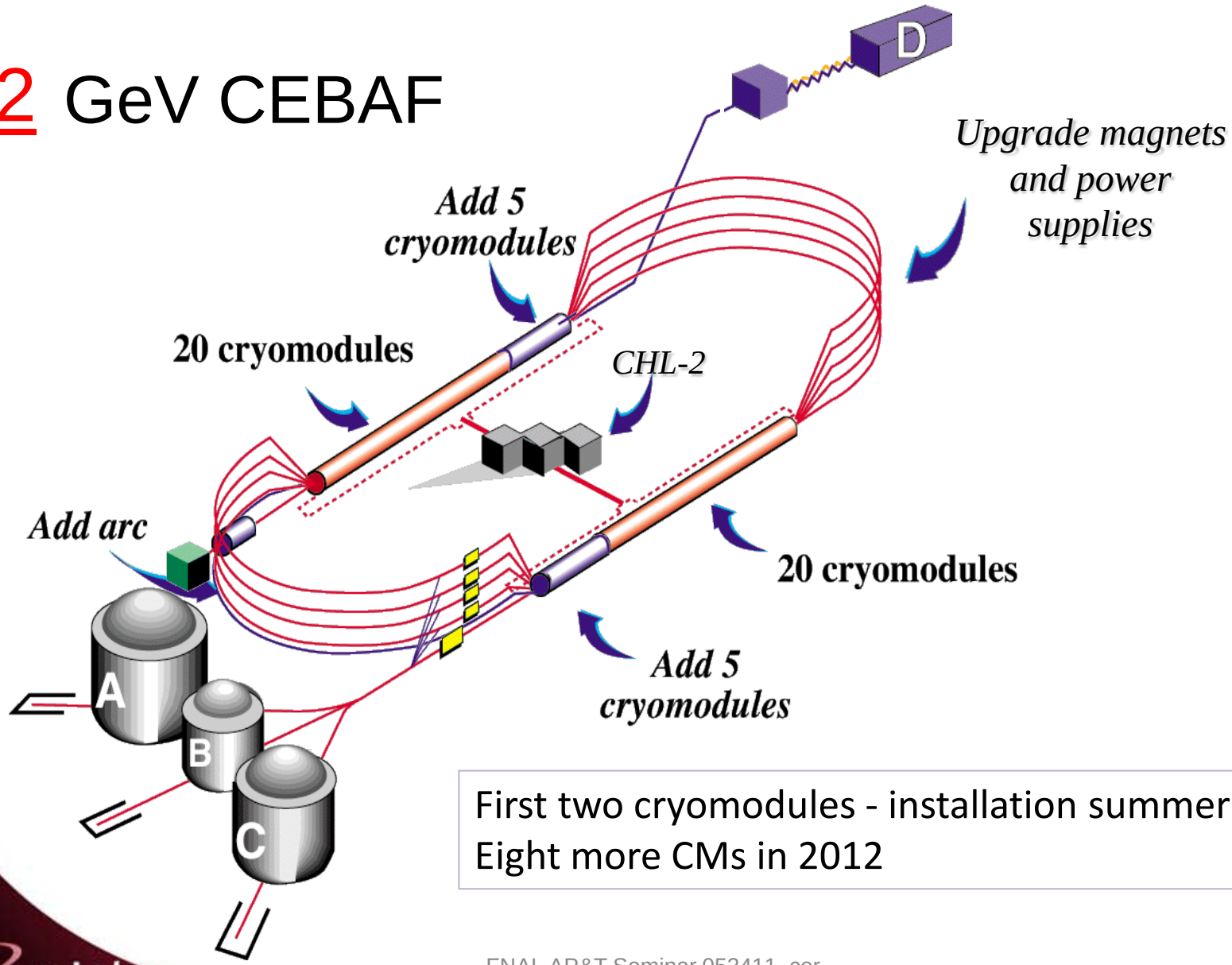
C. Reece

12 GeV Upgrade Cavities

- Project context
  - Requirements
- Production process
  - Sequence and key details
- EP illustration
- VTA test data
- Project status
- Plan for balance of project

CEBAF 12 GeV Upgrade

12 GeV CEBAF



First two cryomodules - installation summer 2011
Eight more CMs in 2012

Key Project Parameters

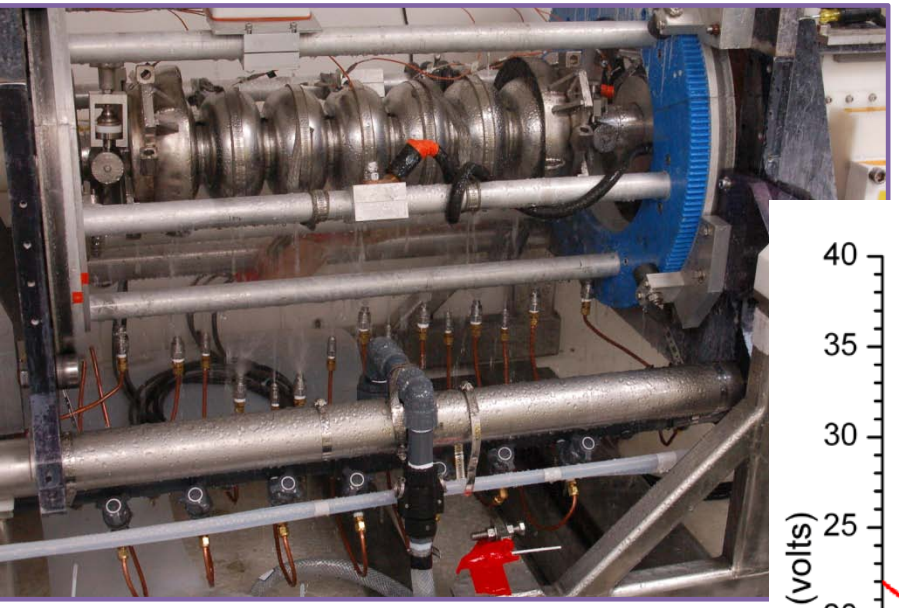
New cryomodules :	10
Voltage per cryomodule:	≥ 108 MV avg.
Cavities per cryomodule:	8
Heat budget:	
• @ 2.07 K	≤ 300 W / CM
•	≤ 29 W / cavity, avg.
Cavity:	1.497 GHz
	0.7 m
	"Low loss" cell shape
Higher order mode damping:	
• Transverse (R/Q)Qk	< 2.4 x 10^{10} Ω/m
• Longitudinal (R/Q)Q	< 6.5 x 10^{11} Ω

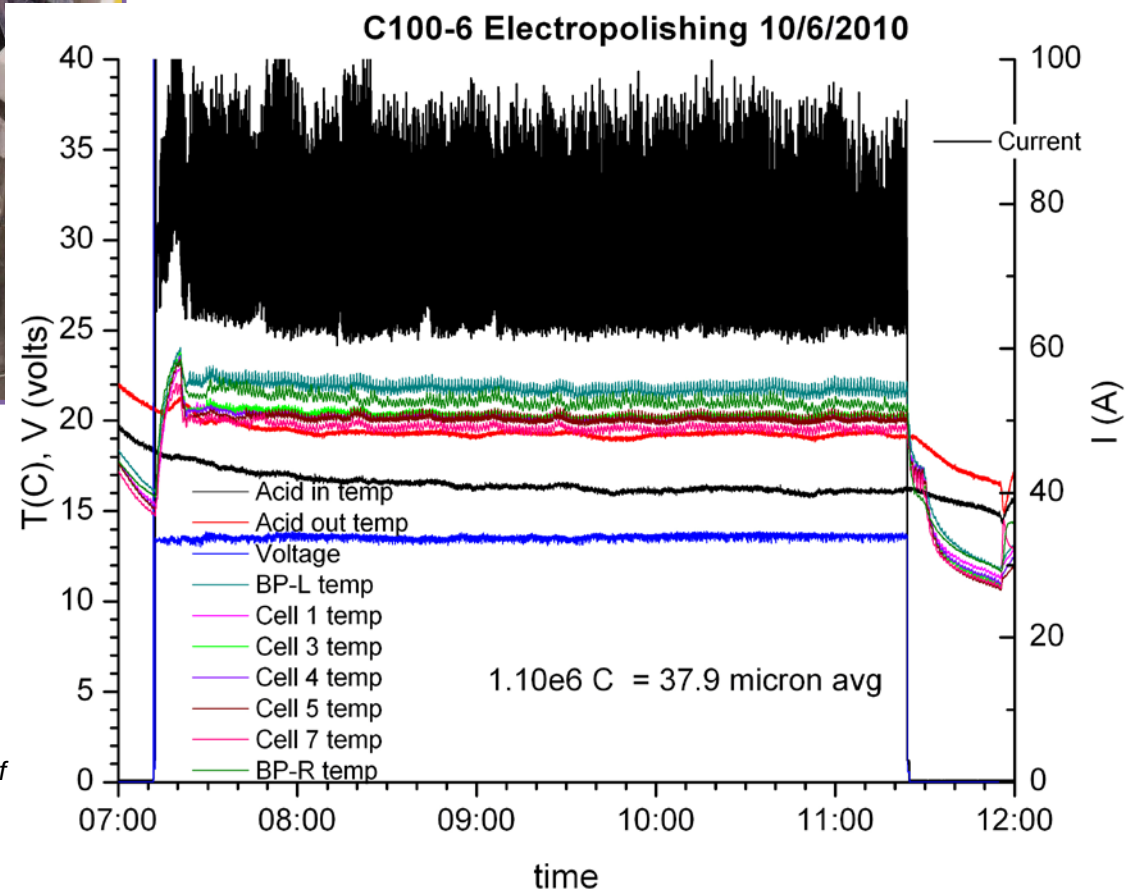
12 GeV Upgrade Cavities

- **Production process**
  - 160 µm BCP and pre-tuned by vendor
  - Receipt inspection – mechanical and rf
  - US >> Bake: 600 C, 10 hrs
  - US >> EP: 30 µm, @20°C regulated by external water spray
  - US >> Tune
  - Helium vessel welding
  - Flange lapping
  - HPR
  - Partial assembly
  - HPR >> dry in Class 10 cleanroom
  - Final assembly, leak check
  - Bake: 120 C, 24 hrs
  - Vertical test @ 2.07 K
  - HPR >> dry in Class 10
  - String assembly

12 GeV Upgrade Cavities

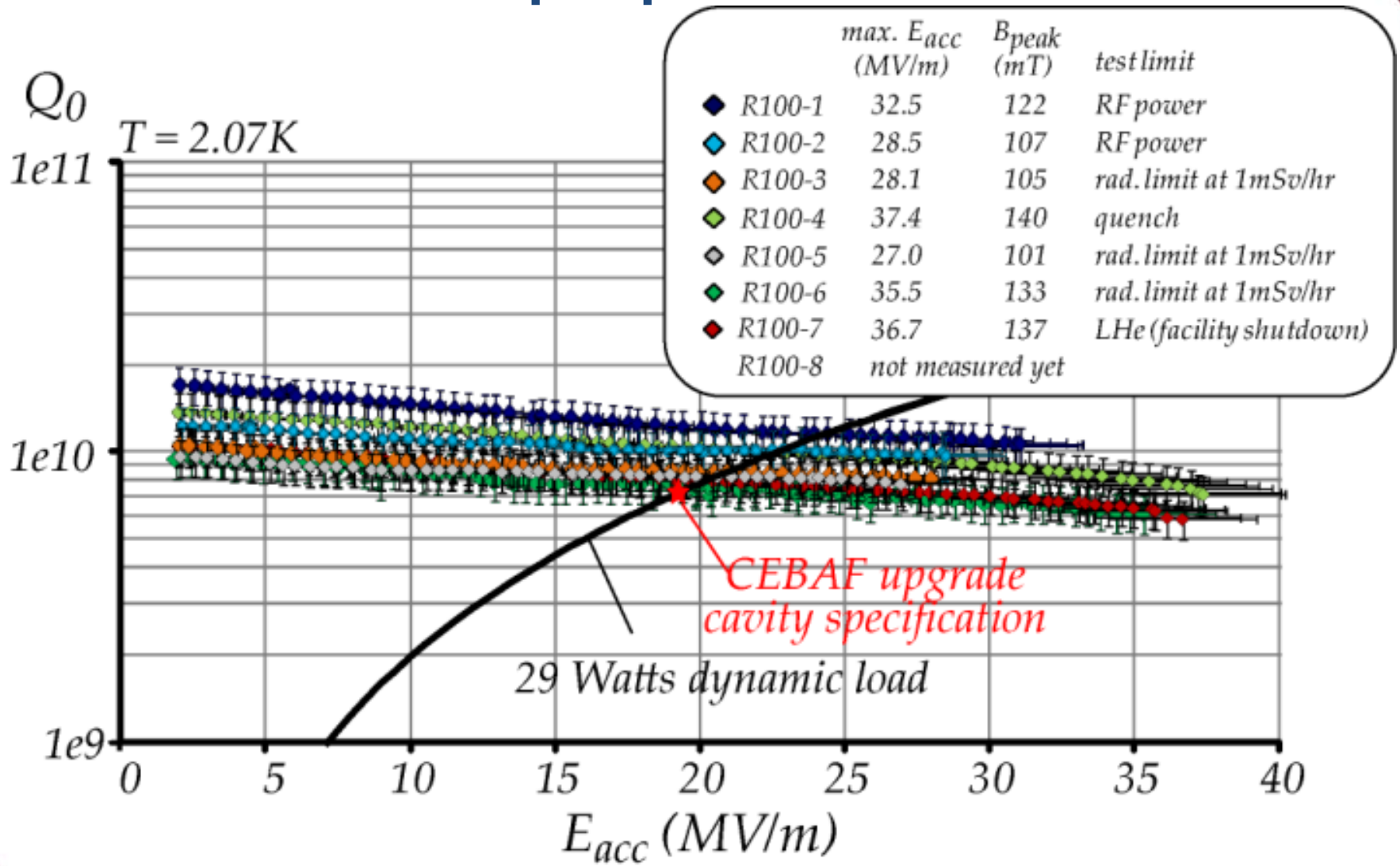
- Improved EP process is now standardized and controlled





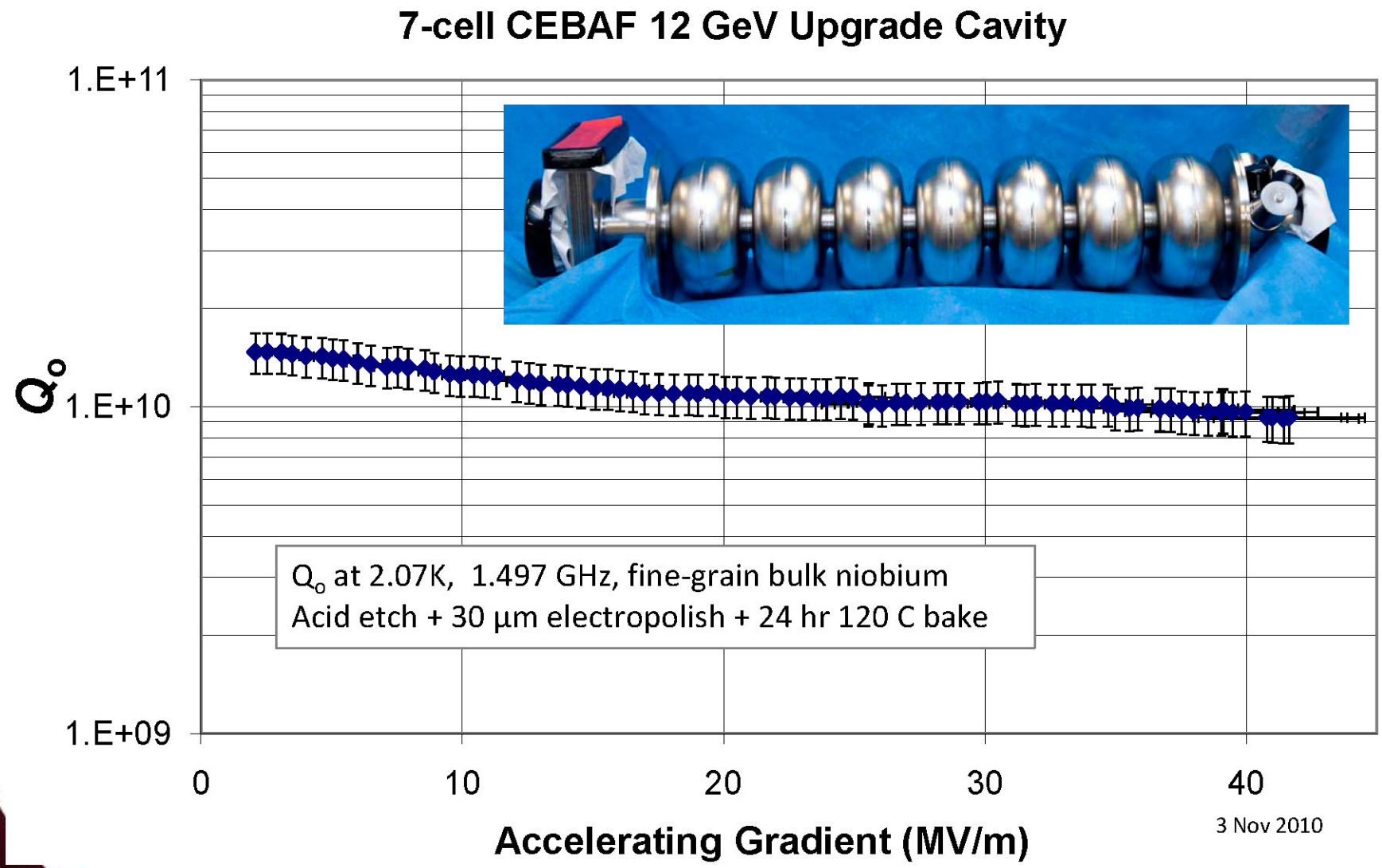
Exploiting New Electrochemical Understanding of Niobium Electropolishing for Improved Performance of SRF Cavities for CEBAF
C. E. Reece and H. Tian, LINAC10 **THP010**

In-house fabricated pre-production cavities



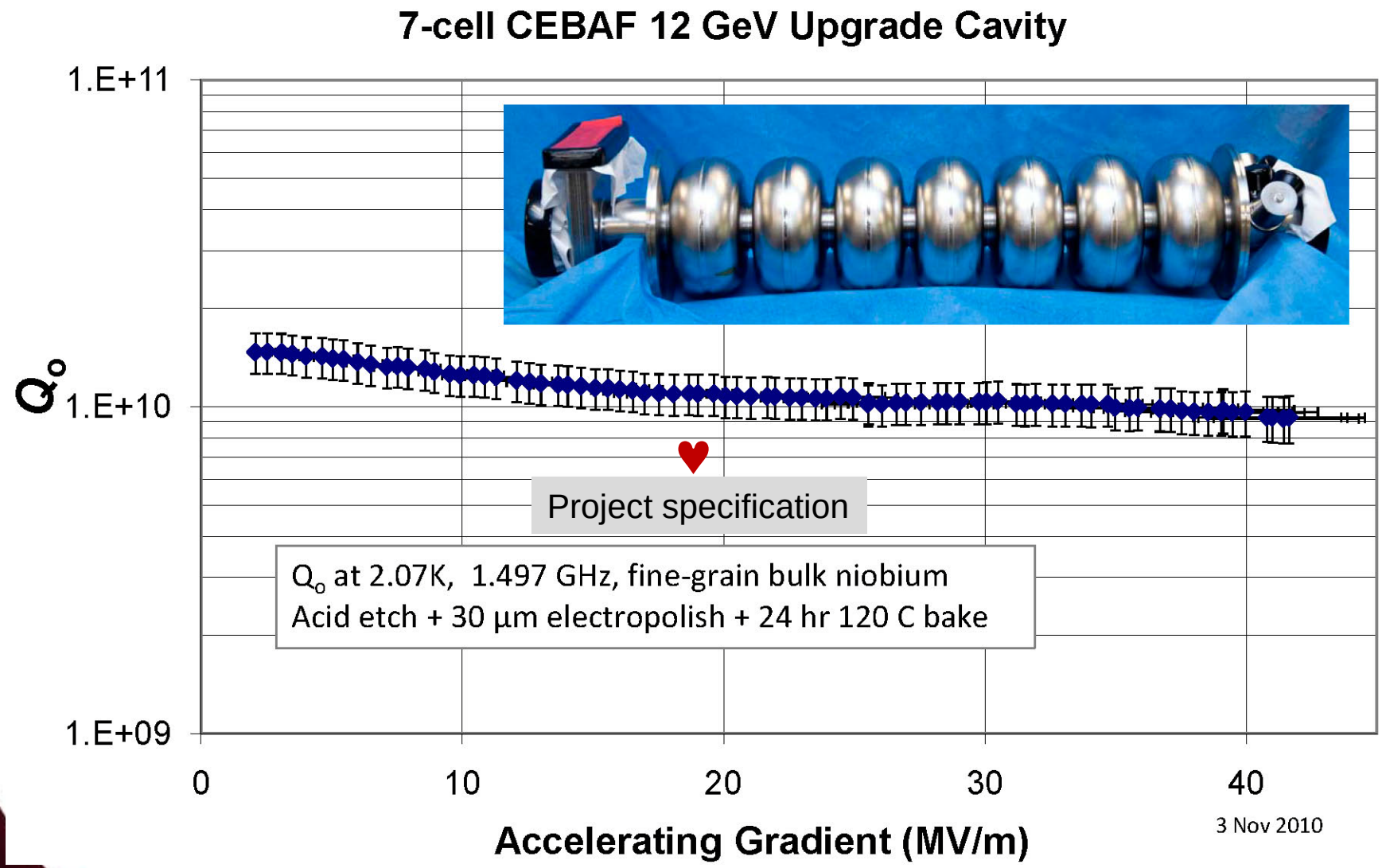
Critical Dipole Modes in JLab Upgrade Cavities
F. Marhauser et al. LINAC10 THP009

State-of-the-art production SRF cavity



Q is BCS-limited

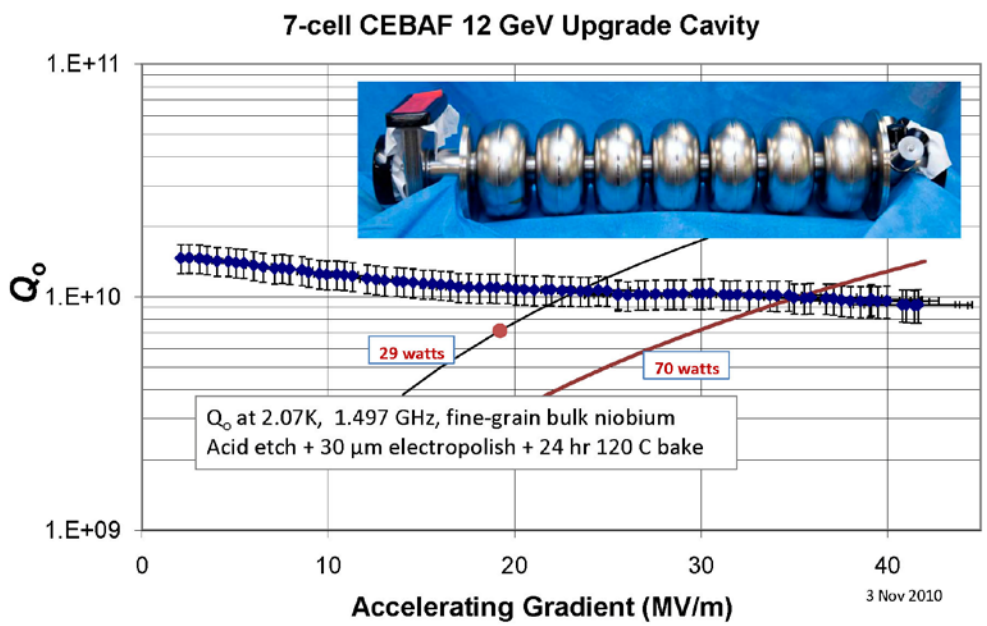
State-of-the-art production SRF cavity

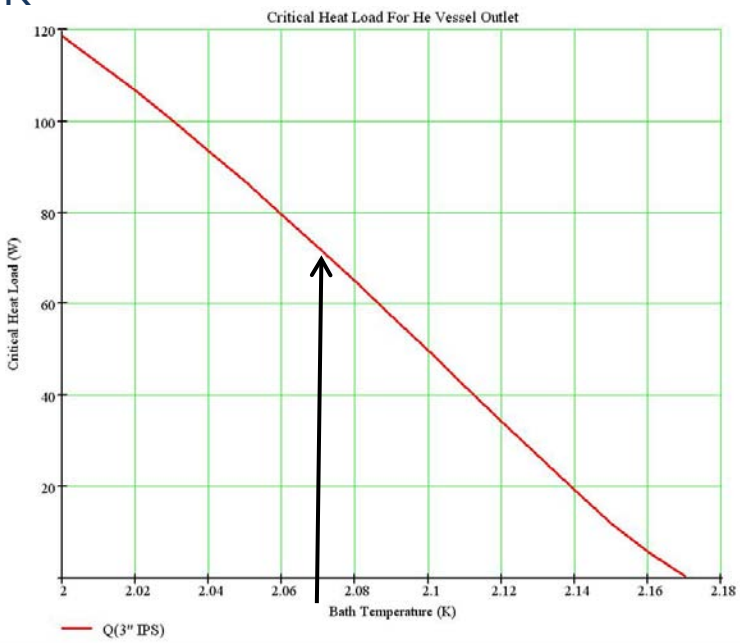


Q is BCS-limited

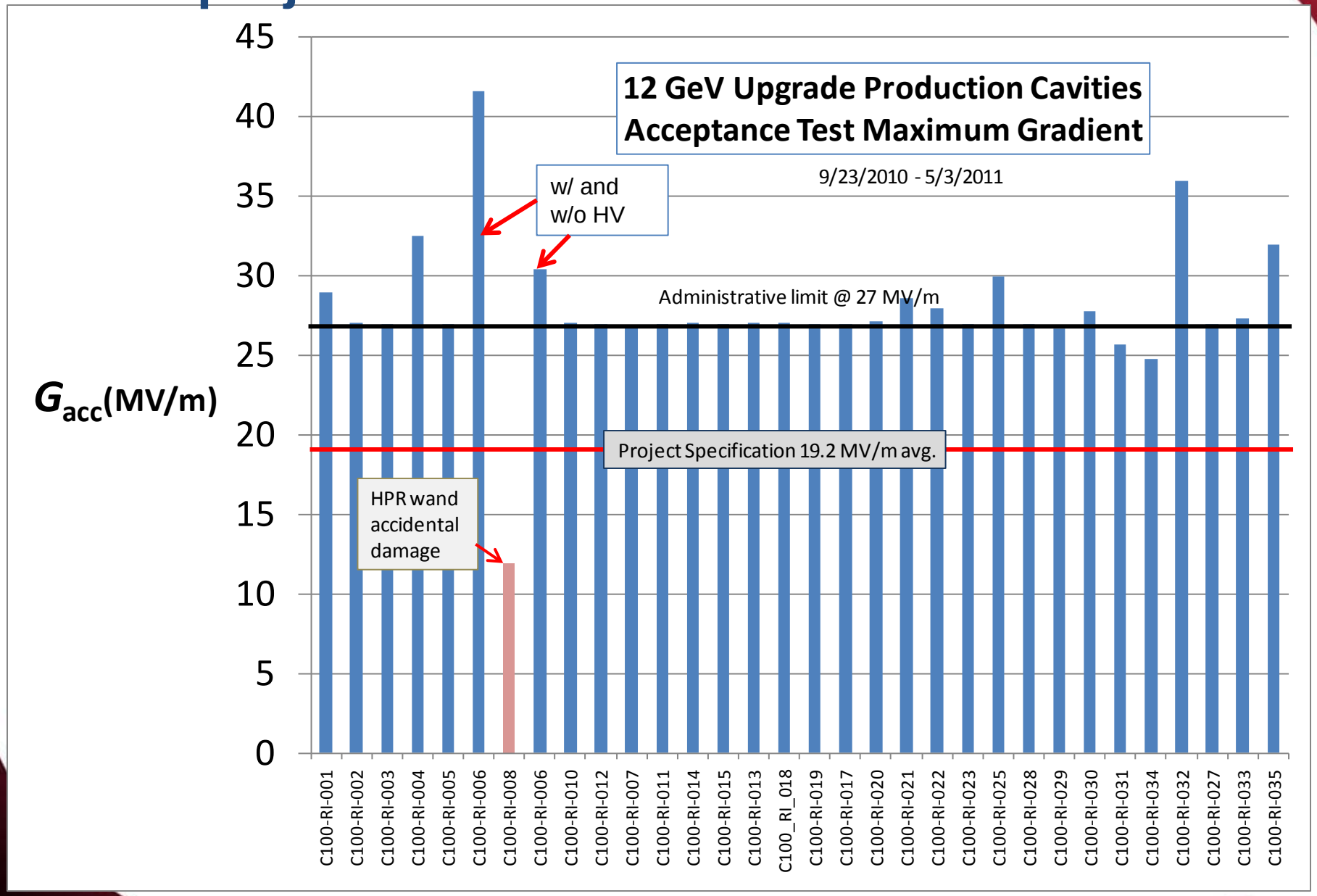
12 GeV Upgrade Cavities

- Project specification: **19.2 MV/m** average, with 29 W avg. heat
- Operational limit in CEBAF, RF power: **25 MV/m**
- Project conservatism for first two CMs:
  - To avoid any potential risk of degradation from "pushing,"
  - **Limiting vertical cavity acceptance testing to 27 MV/m**
  - (rather frustrating to us cavity people who look into the future)
- Vertical rf test only after HV attached
  - Piping size limits heat load to ~70 watts @ 2.07 K





12 GeV project cavities



JLab CEBAF Upgrade Cavities - May 2011

- **C100 cavity – production system is running**
  - 84/86 cavities received
  - 50/86 cavities EP'd (2/wk)
  - 31/86 cavities VTA tested
  - 30/86 cavities qualified in HV (1 damaged)
  - 16/80 cavities = 2/10 strings completed, ready for #3
  - Procedure suite established and tracked
  - No SRF performance issues currently open

- Found weak spec on SS helium vessel material
  - High permeability, degraded cavity Q
  - Found early, material replaced
  - Issue was resolved quickly
- Analyzing microphonic sensitivity in CM – (no stiffening rings)

12 GeV Upgrade Cavities

- Production cavity tracking screen

Pansophy
A System of Universal Knowledge

you have been authenticated
who am i | click here to logout

Travelers | Logbooks | Support | DocuShare

C100 Cavity Status Board

Serial ID	INSP	RFIN	PreHeat DEGR	HEAT	THKN	PreEP DEGR	EPOL	PostEP DEGR	TUNE	HELV	LAP	1st HPR	ASSY	2nd HPR	ASSY2	BAKE	VTRF
	C100-CAV-INSP	C100-CAV-RFIN	C100-CAV-DEGR	C100-CAV-HEAT	C100-CAV-THKN	C100-CAV-DEGR	C100-CAV-EPOL	C100-CAV-DEGR	C100-CAV-TUNE	C100-CAV-INST-HELV	C100-CAV-LAP	C100-CAV-HPR	C100-CAV-ASSY	C100-CAV-HPR	C100-CAV-ASSY2	C100-CAV-BAKE	C100-CAV-VTRF
C100-1		16							10 23		1 2 7 18						1
C100-2																	
C100-3													55		82		
C100-4																	
C100-RI-001	1	1	3	1		5 65	2	6 99	2 11	13	17	5 62	1 3 27	3 6 63 100 115	1 3 29	1	2 35
C100-RI-002	2	2	4	2	3 21	7	3	10 103	3 12	14	19	7 65	2 4 28	4 8 94 109	2 4 30	3	3 4 36
C100-RI-003	4	3	8	3	2 2 4	11	4	15 20	4 13	5	8	9 35	5 17	10 36 52	5 18	4	5 15 24
C100-RI-004	6	4	9	4	6 7	14	5	19 25 56	5 14	4	6	11 32	6 16	12 34 47	6 17 19	5	6 16 14
C100-RI-005	7	5	12	5	5 10	18	6	23 27 54	6 15	3	4	13 29	7 15	14 33 51	7 16	6	7 13 17 25
C100-RI-006	8	6	13	6	8 11	73	7	26 30 43 52	7 16	2	3	15 23 27	8 11 12	16 24 28 53	8 12 13	7	8 9 18
C100-RI-007	9	7	16	7	9 12 25	24	8 14	28 34 42 55 66	8 17 25	9	5 12	17 21 30 43	9 14 21	18 31 44 49	9 15 23	8 9	12 19
C100-RI-008	10	8	17	8	14 17	74	9 32	33 38 50 79 133	9 18 19 40		13 32	19 25 55	10 13 23 53	20 22 26 56 64	10 11 14 25 31 69	10	10 11 26 37
C100-RI-009	12	9	21	9	13 15	29	10	36	20								
C100-RI-010	11	10	22	10	18 19	32	11	39 60	21	6		38	18	40 48	20	12	21
C100-RI-011	13	11	31	11	16 22	37	12	41 59 70	22	7	9 10	37 45	19 22	39 46 54	21 24	11	22 23
C100-RI-012	14	17	35	12	20 23	40	13	61	24	8	11	41	20	42 50	22		20
C100-RI-013	17	14	49	13		62	19	71 92	29	11	16	60	26	61 68 93 108	28 33	15	31 38
C100-RI-014	18	15	53	14		57	17	76 84	26	10	14	57	24	58	26	13	30
C100-RI-015	15	12	44	15	24 26	46	15	47 88	27	12	15	59	25	99 113	27	14	32
C100-RI-016	38	22	69	21		87	23	91	31	17	45		51		68	35	
C100-RI-017	16	13	45	16		48	16	51 106 123	28	15	20 25	66 75	29 33	67 76 78 101 116	32 37	16	39 42
C100-RI-018	19	18	58	17		75	18	77 109	30	16	21	69	30	70 95 110	34	17	40
C100-RI-019	20	19	64	18		68	20	72 118	32	18	22	71	31	72 96 111	35	18	41
C100-RI-020	22	20	63	19		78	21	80 119	33	19	23	73	32	74 86 97 112	36 42	19	43 46
C100-RI-021	23	21	67	20		81	22	85 124	35	20	24	77	34	79 87 89	38 43 45	20	44 47
C100-RI-022	24	23	82	22		90	24	95 96 128	34	21	26		35	81 88	39 44	21	45 48
C100-RI-023	25	24	83	23		89	25	101 135	36	22	27	82	36	83 90	40 46	22	49
C100-RI-024	61		145	42			41	155	49		46						
C100-RI-025	26	25	86	24 25	27	98	26	107 138	37	23	28	84	37	85 98	41 48	23	50 51
C100-RI-026	27 62	45	156	44			46	168	55								
C100-RI-027	29	26	93	26		104	27	108 143	38	24	29 34 36	91 114 125	38 42 45	92 117 126	47 52 58 60 67	30	59

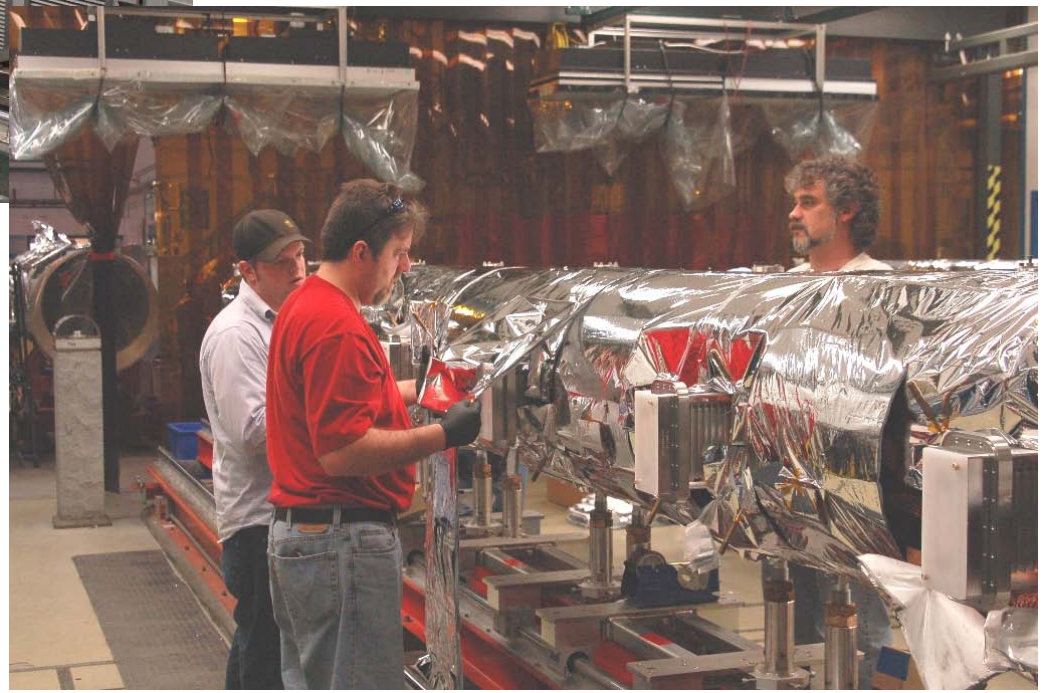
Done

JLab SRF Cavity Team - 2011

(B. Carpenter, T. Reilly, F. Marhauser, and R. Geng missing)

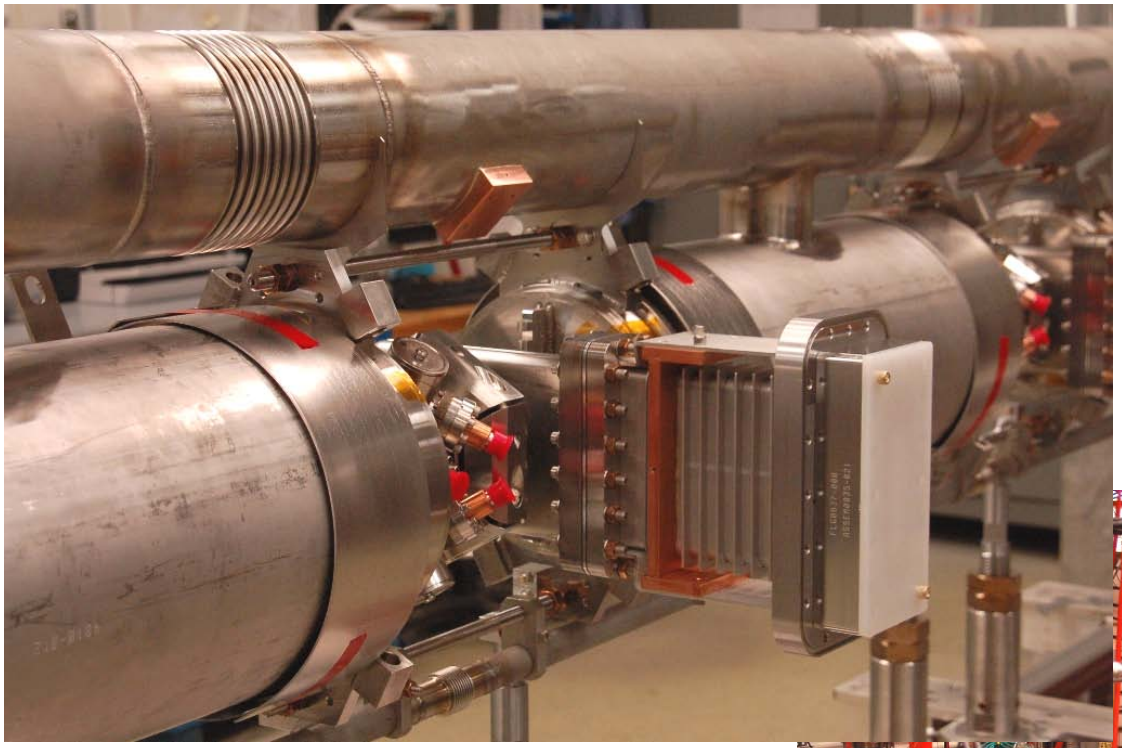
12 GeV Upgrade Cryomodule

First cavity string

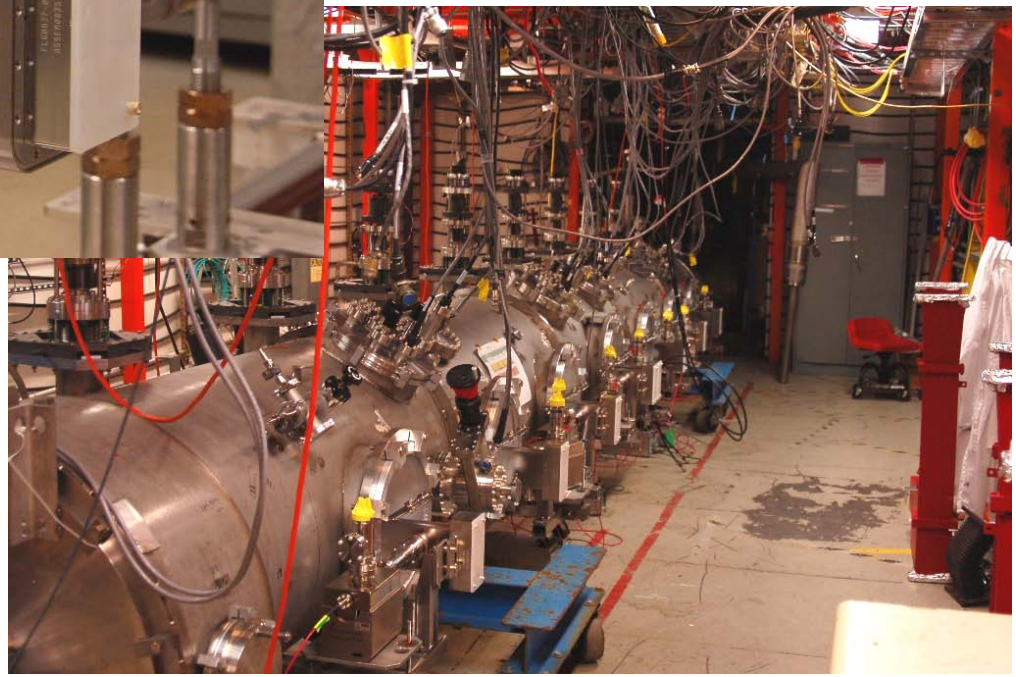


Installation of super-insulation on upgrade cryomodule

“C100” cryomodule assembly and testing



Cavity string with He piping

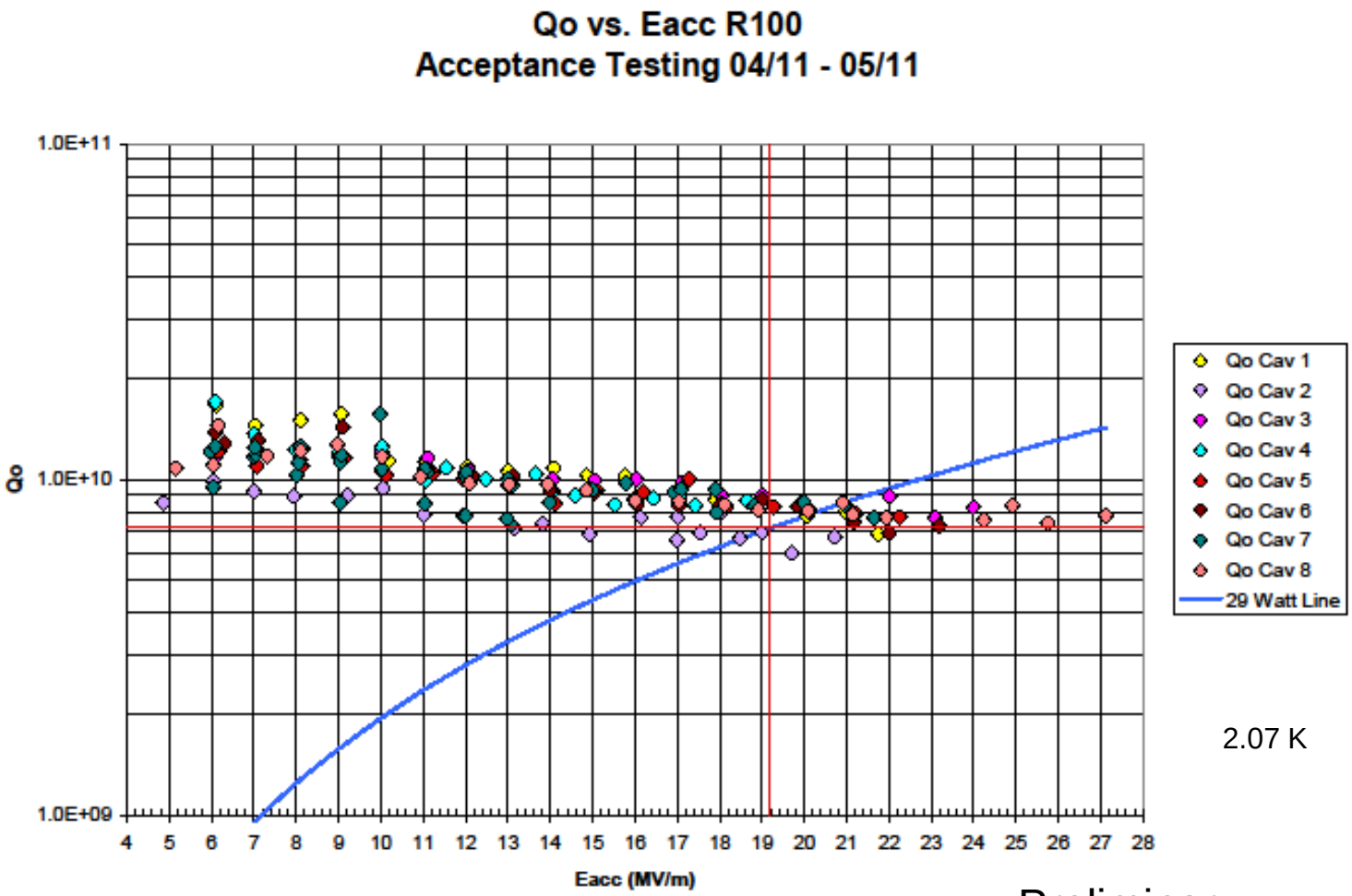


R100 cryomodule in test cave

R100 Cryomodule Performance

In-house fabricated upgrade-style cavities

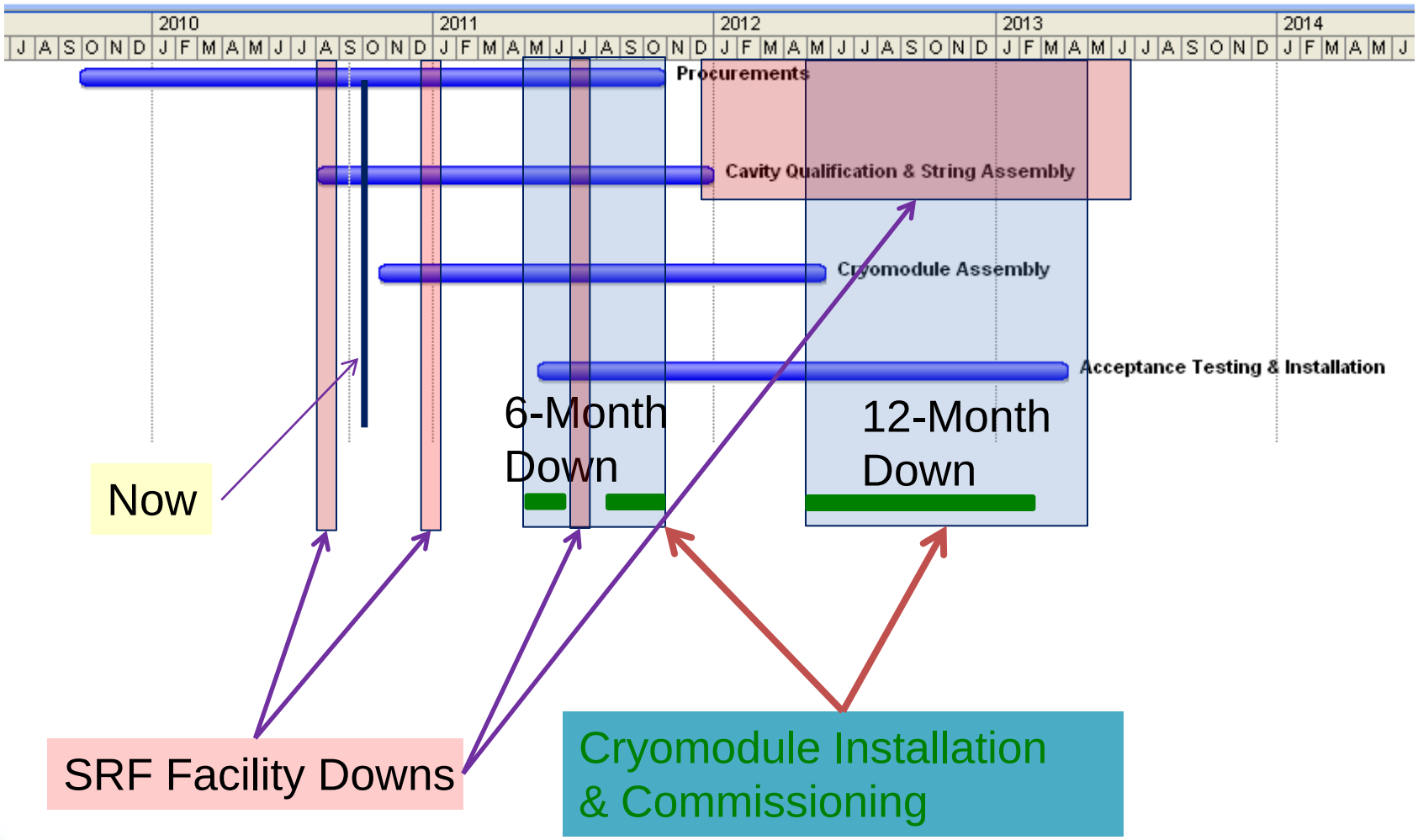
Static 2 K load: 22 W
Static 40 K shield load: 240 W



2.07 K

Preliminary

Baseline Work Plan Coordinated with TEDF



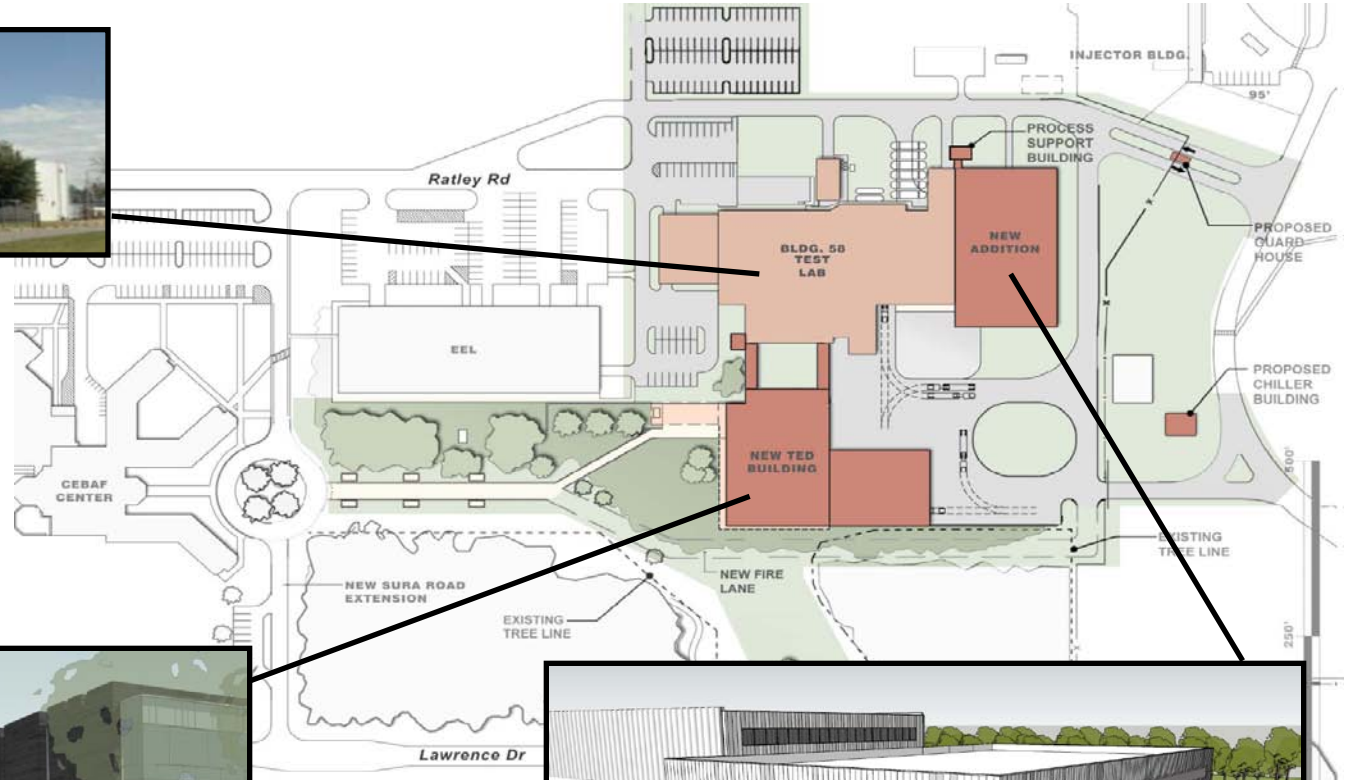
JLab SRF Facilities Upgrade Plans

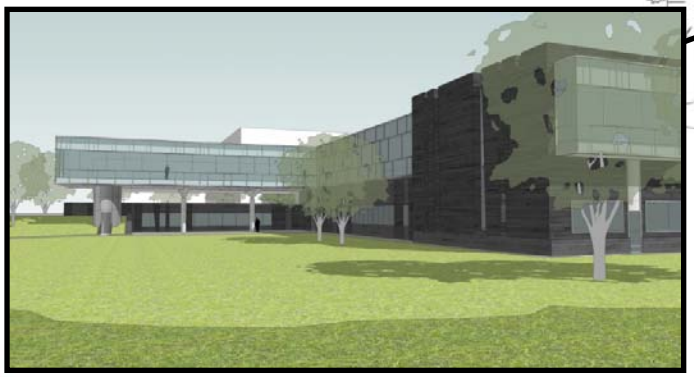
TEDF Project

- Technology and Engineering Development Facility
  - Motivations
  - Overview
- SRF facility changes
  - Overview
  - Attention to chemical processing
  - Photo album

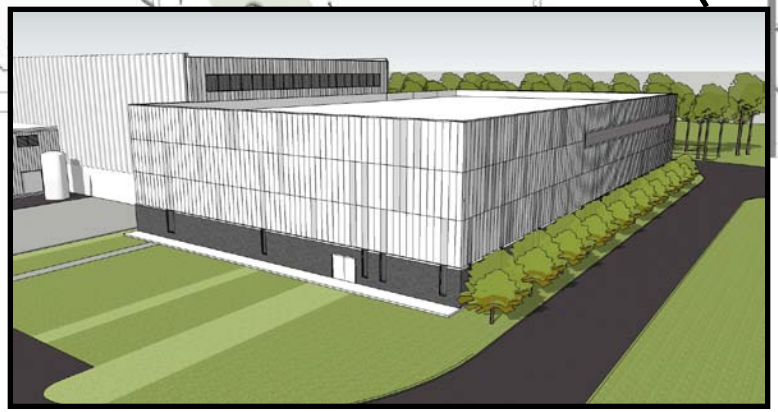
TEDF Project

Test Lab Renovation





TED Building



Test Lab Addition

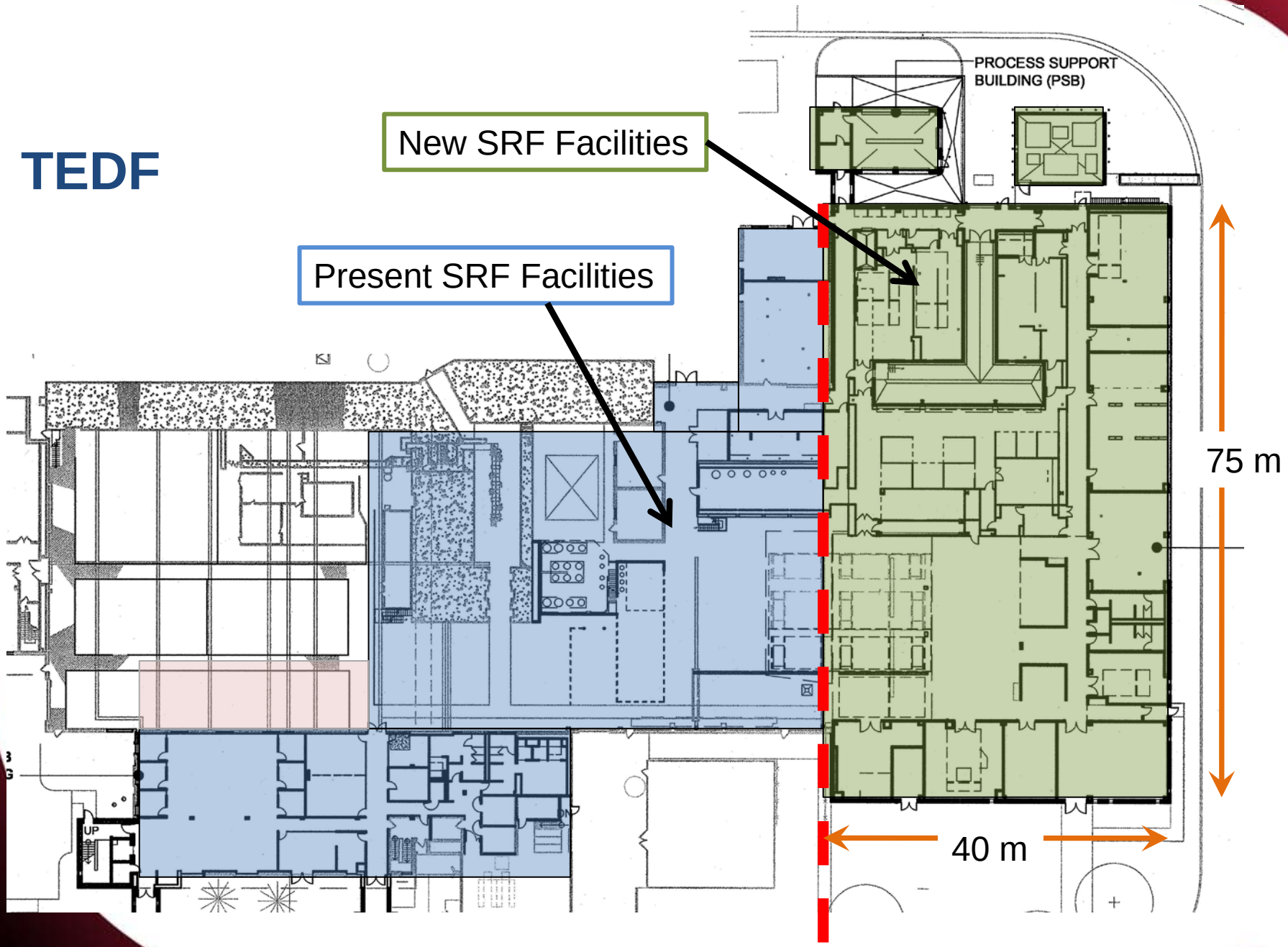
TEDF Project

- **Department of Energy – "Science Laboratory Infrastructure" Project**
- Investment in facilities for:
  - Improved energy efficiency
  - Improved life-safety code compliance
  - Improved work-flow efficiency
  - Improved facility sustainability
  - Improved human work environment
  - Improved technical quality of facilities for future work
  - Increased build-out capacity
- Will provide new home for JLab orgs:
  - SRF Institute
  - Engineering division
  - Physics instrumentation groups

TEDF

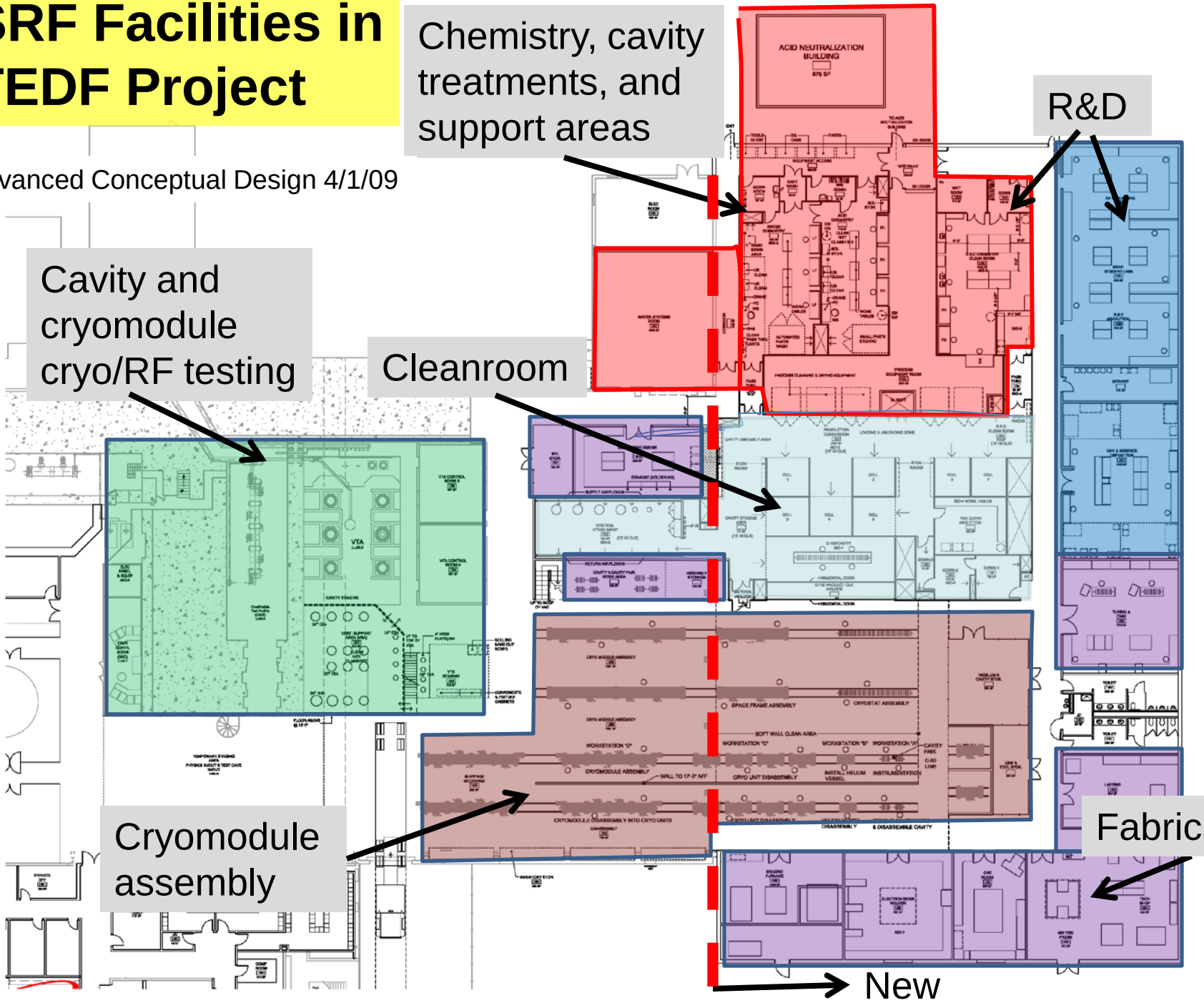
TEDF

TEDF


New SRF Facilities
Present SRF Facilities
PROCESS SUPPORT BUILDING (PSB)
75 m
40 m
UP

SRF Facilities in TEDF Project

Advanced Conceptual Design 4/1/09



Cavity testing – (VTA)

April VTA activity

VTA will survive the renovation with expanded staging area, otherwise unchanged.

date	dewar 1	dewar 2	dewar 3	dewar 4	dewar 5	dewar 6	dewar 7	dewar 8	CM cold?	CTF Refill rate (%/hr)
1	fill, pump		fill, pump, fill from D7	2K	4K	fill, pump	warm up		N	4.3
2			warm up	fill, pump	4K		warm up	ill, pump, fill from D3,	N	4.1
3			warm up	2K	4K			2K	N	idle
4				warm up	4K	fill, pump	ill, pump, fill from D4,	warm up	N	4.5
5		fill, pump	fill, pump	warm up	fill	fill, pump	fill, pump	warm up	N	5.5
6			warm up		fill from D3, 7	fill, pump	warm up		Y	4.8
7			fill, pump, fill from D	fill, warm to 100K	4K		warm gas path		Y	3.7
8	fill, pump		fill, pump	fill	4K	fill, pump	warm gas path	fill	Y	4.4
9			warm up	fill	fill	warm up	warm gas path	fill, pump, fill from D3	Y	5.3
10			warm up	4K	4K		warm gas path	2K	Y	idle
11	cool to 5K		warm gas path	fill, pump	fill from D8			warm up	Y	3.6
12	cool to 5K			warm up	fill from D4		fill		Y	4.7
13	warm up		warm gas path		4K	fill, pump	fill, pump	fill	Y	4.9
14	cool to 5K	fill	warm gas path	fill	4K	fill, pump	warm up	fill, pump, fill from D7	Y	4.9
15	fill	fill	warm gas path	fill, pump	4K	fill, pump	fill, pump, fill from D8	warm up	Y	3.7
16		fill, pump	warm gas path	warm up	fill from D4	warm up	4K	warm up	Y	3.9
17			warm gas path	warm up	4K		4K		Y	idle
18	fill, pump		fill		4K		fill, pump		Y	3.7
19	fill	fill	4K		4K	fill, pump	warm up	fill, pump, fill from D7	Y	4.2
20		fill, pump	fill		4K		warm up	fill, pump	Y	2.7
21		cool to 5K	fill, pump	warm gas path	4K	fill, pump	fill, pump, fill from D8	warm up	Y	1.2
22	fill	cool to 5K	warm up		4K	fill, pump	fill, pump		Y	4.9
23					4K		2K		Y	idle
24					4K		2K		Y	idle
25				fill, pump, fill from D7	4K	fill, pump	warm up	fill	Y	4.9
26	fill	fill	fill	2K	4K			warm up	Y	4.5
27			pump, fill from D4, 5	warm up	4K		fill	warm gas path	Y	3.5
28	fill	fill	warm up, fill, pump		fill from D3	fill, pump	4K	warm gas path	Y	5.2
29	fill	fill, pump	warm up	warm gas path	4K	fill, pump	fill, pump	fill	Y	1.6
30			fill, pump	warm gas path	4K	warm up	warm up	fill, pump, fill from D7	Y	4.4
		R & D	ILC	12 GeV	Jlab 7-cell		VTA/CTF Maint. dowr	CM cooldown, pump		
			SNS	Jlab 9-cell	BNL Gun	weather	VTA/CTF Crash	power outage		
								Hall D Coil Cooldown		

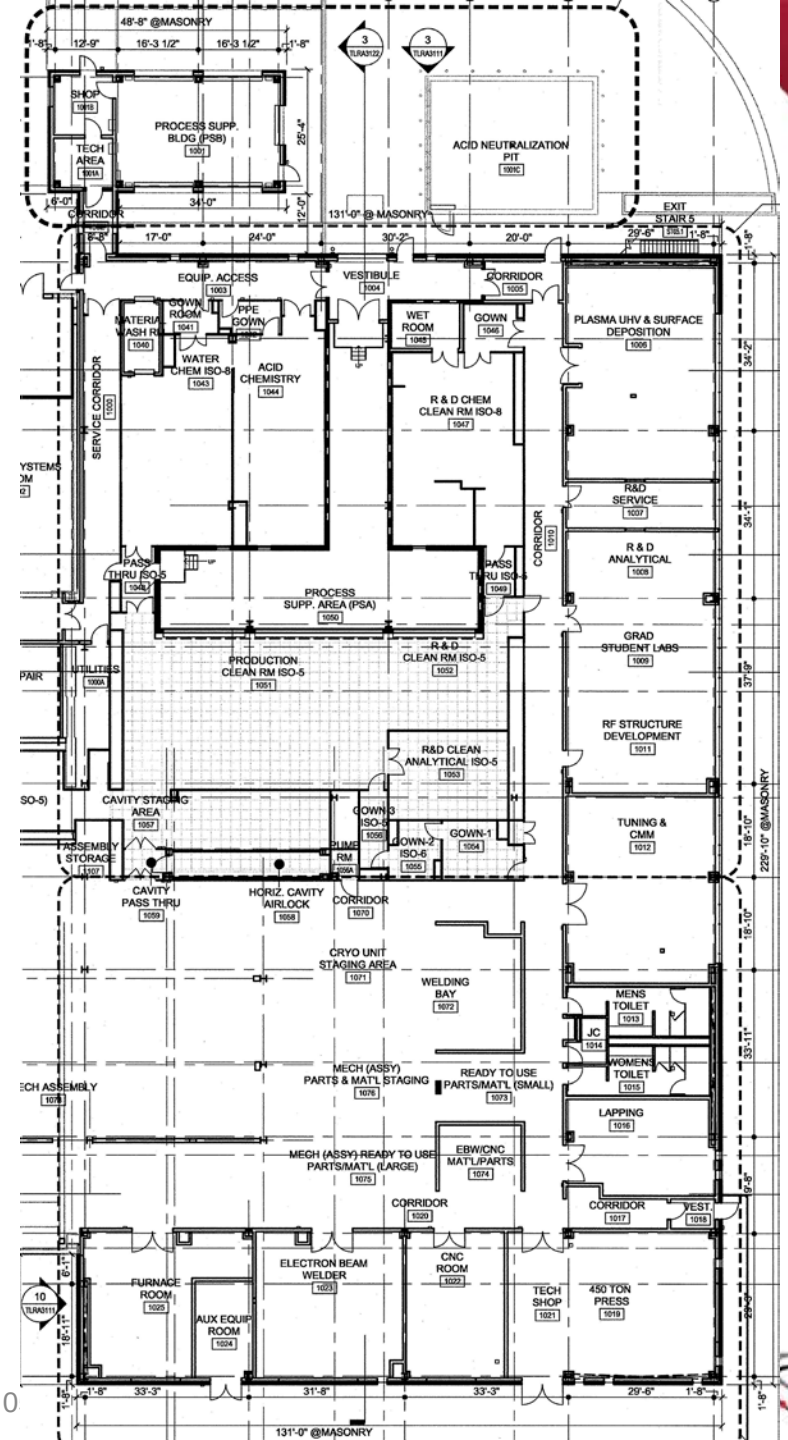
>3440 test cycles and counting…
27 different styles of multi-cell cavities + uncounted single cells

Cryogenic supply system recently upgraded with help from FNAL ARRA “through-put” improvement contribution. Speeds fill and increases LHe draw capacity - thanks

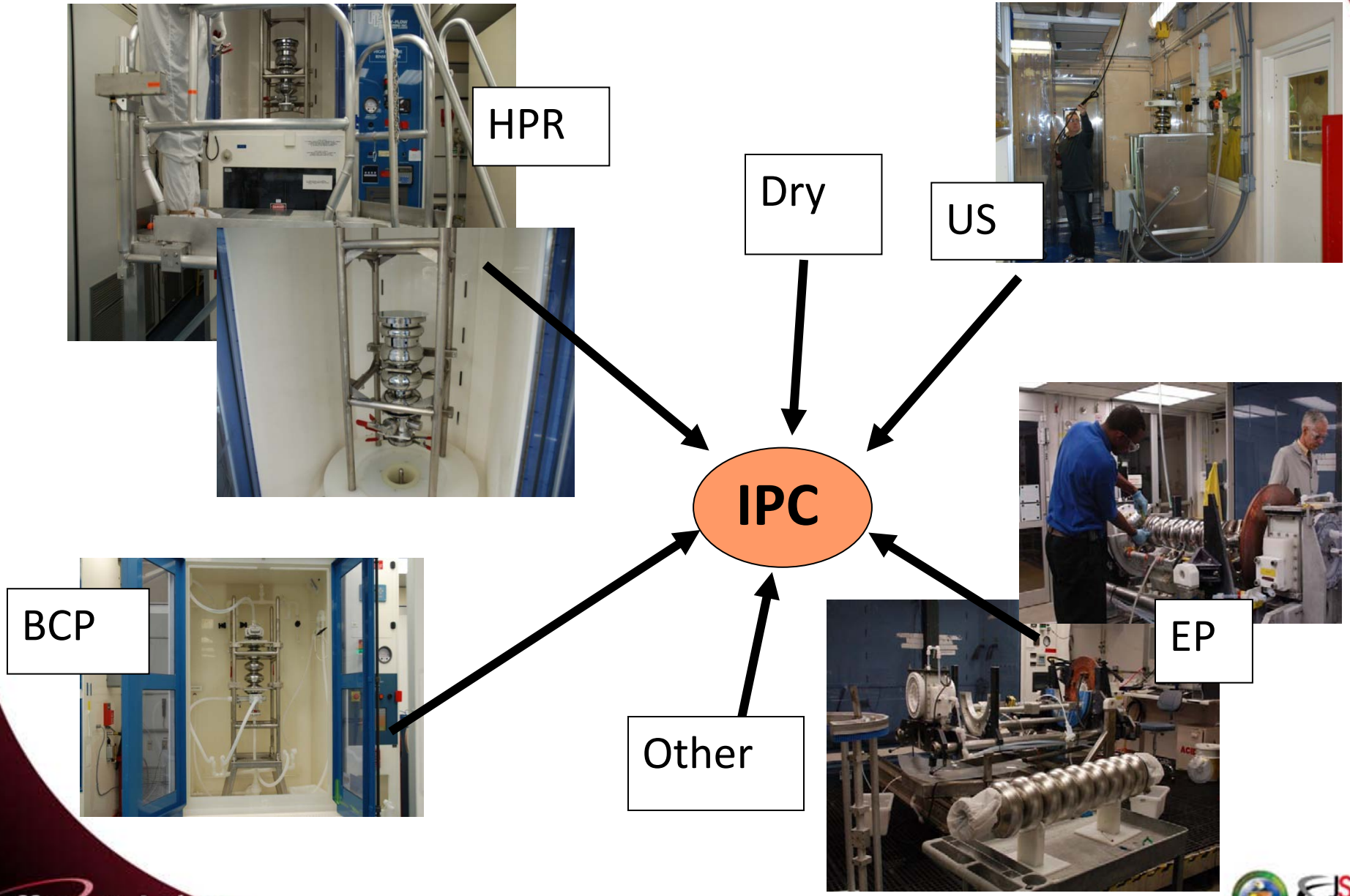
TEDF Infrastructure Design

30,000 sf – new

Cavity fabrication (presses, EBW…)
RF structure development
Process development
QC/ Inspection
Clean analytical lab
Production chemroom
R&D chemroom
Flexible ISO 4 cleanroom suite
Dedicated CEBAF-support CM assembly lines
Expansion space for other DOE project support



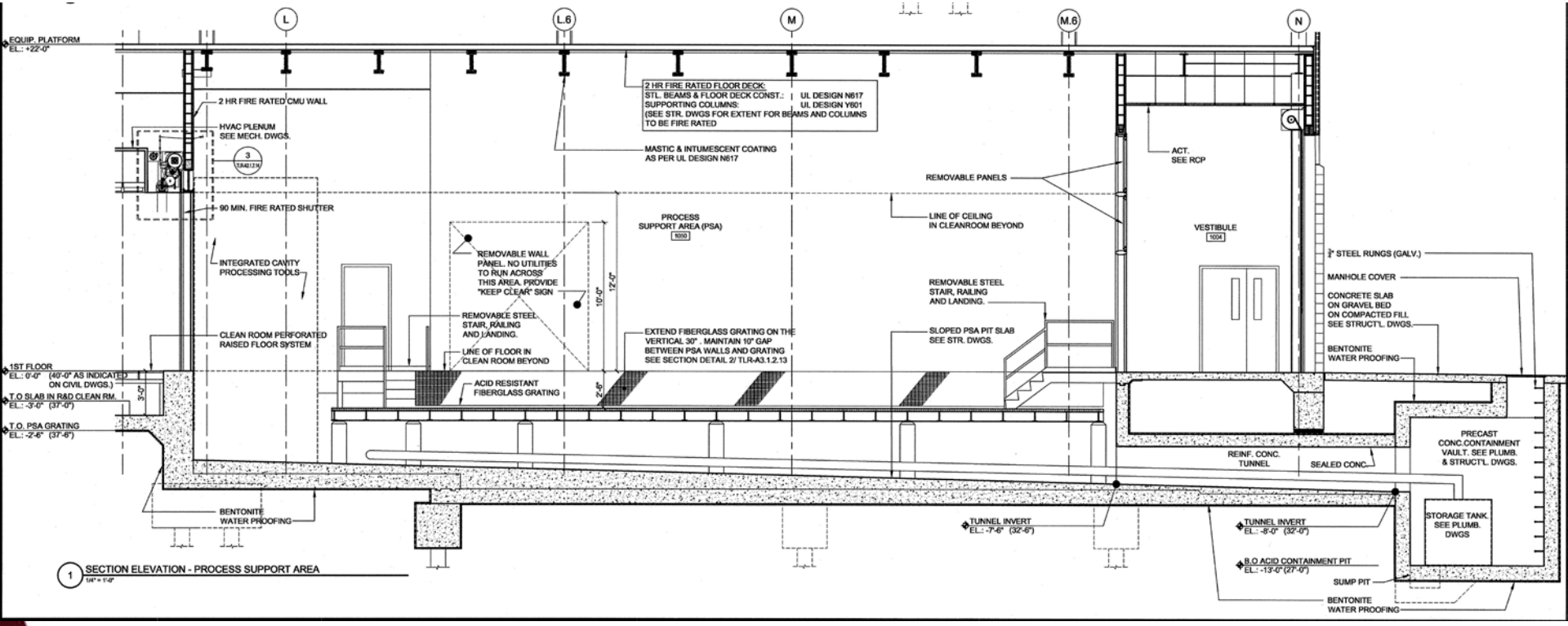
ICP (Integrated Cavity Processing) tool concept will integrate multiple process steps with minimum handling in new TEDF facilities



TEDF Infrastructure Design

Integration of cleanroom/chem processing/waste collection

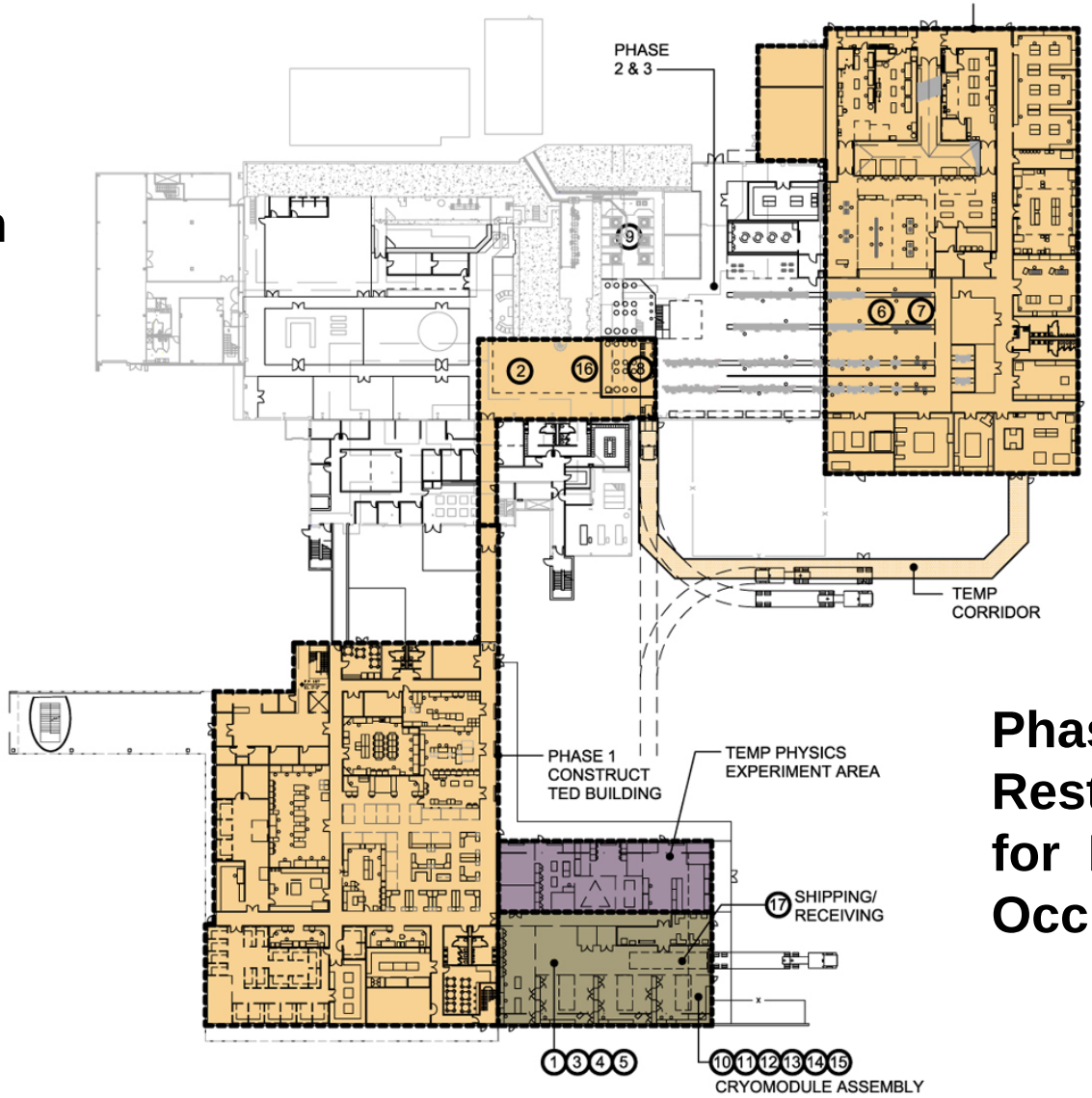
Architectural elevation through process support area



TEDF Project Phasing

Phase 2: Prep Bldg 58 for Shutdown

Phase 3: Renovate Bldg 58



Phase 1: Construct TED Bldg & Test Lab Addition

Phase 4: Restore TED Bldg for Final Occupancy

TEDF Summer 2010

TEDF Feb 2011

TEDF April 2011

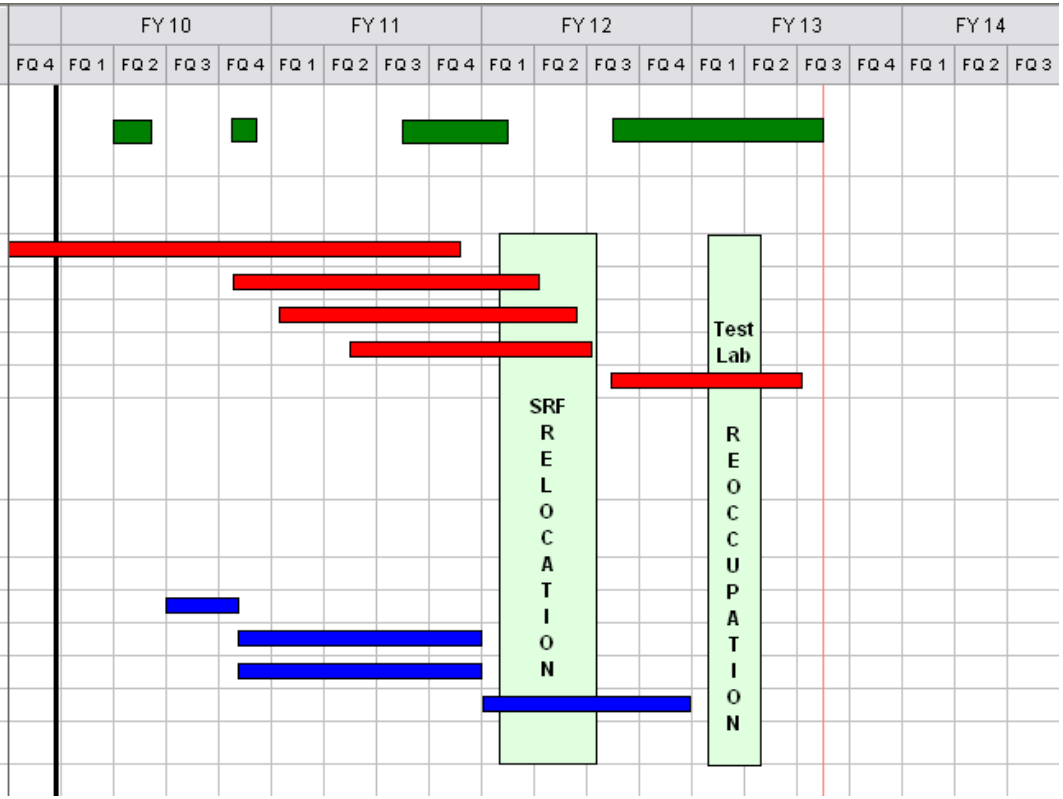
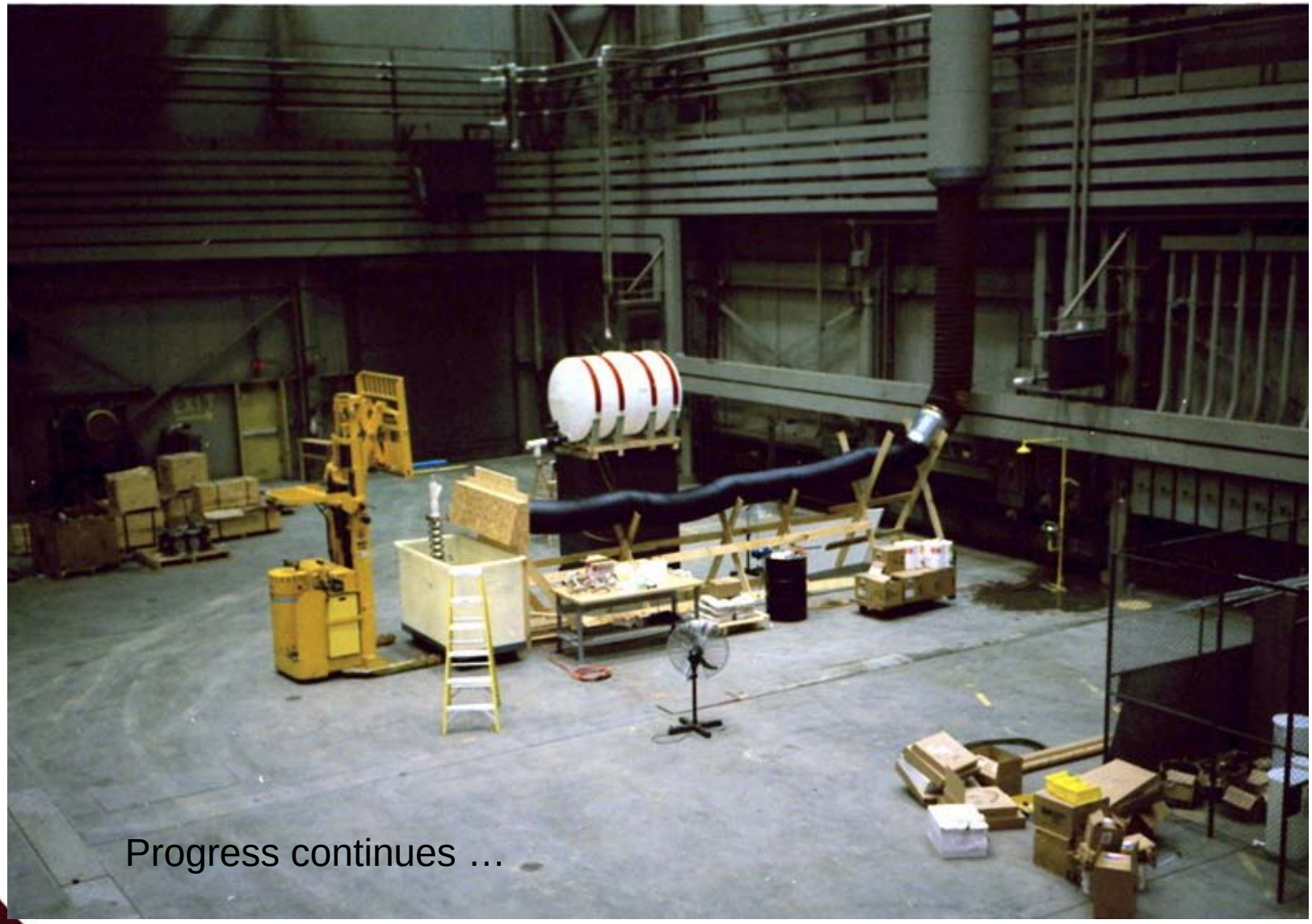
Demolition of Acid Transfer building

Commissioning of new
Process Support Building (PSB)

TEDF May 2011

TEDF Project Schedule

	Activity Name	Start Date	Finish Date
1	Accelerator Down Periods	1/1/10 7/23/10 5/16/11 5/15/12	3/5/10 9/3/10 11/15/11 5/15/13
6	12 GeV Cryomodule Schedule		
7	1.3.1.1 Procurements	1/2/09	8/23/11
8	1.3.1.2 Cavity String Assembly	7/26/10	1/9/12
9	1.3.1.3 Cryomodule Assembly	10/14/10	3/13/12
10	1.3.1.4 Cryomodules Acceptance Test	2/16/11	4/9/12
11	1.3.1.5 Cryomodule Installation & Test	5/14/12	4/10/13
12			
13	TEDF Schedule		
14	**Early Start/Finish**		
15	6.3.1.1 Civil/Site & Early Procurements	3/31/10	8/3/10
16	6.3.1.2 TED Building Construction	8/4/10	9/30/11
17	6.3.1.3 TL Addition Construction	8/4/10	9/30/11
18	6.3.1.4 TL Renovation	10/3/11	9/28/12
19			
20			



Ante-TEDF (First JLab cavity processing facility– 1988)