The CEBAF Performance Plan: C75 and Energy Reach

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CPP Energy Reach Gap Analysis

CPP Overview: JLAB-TN-17-022

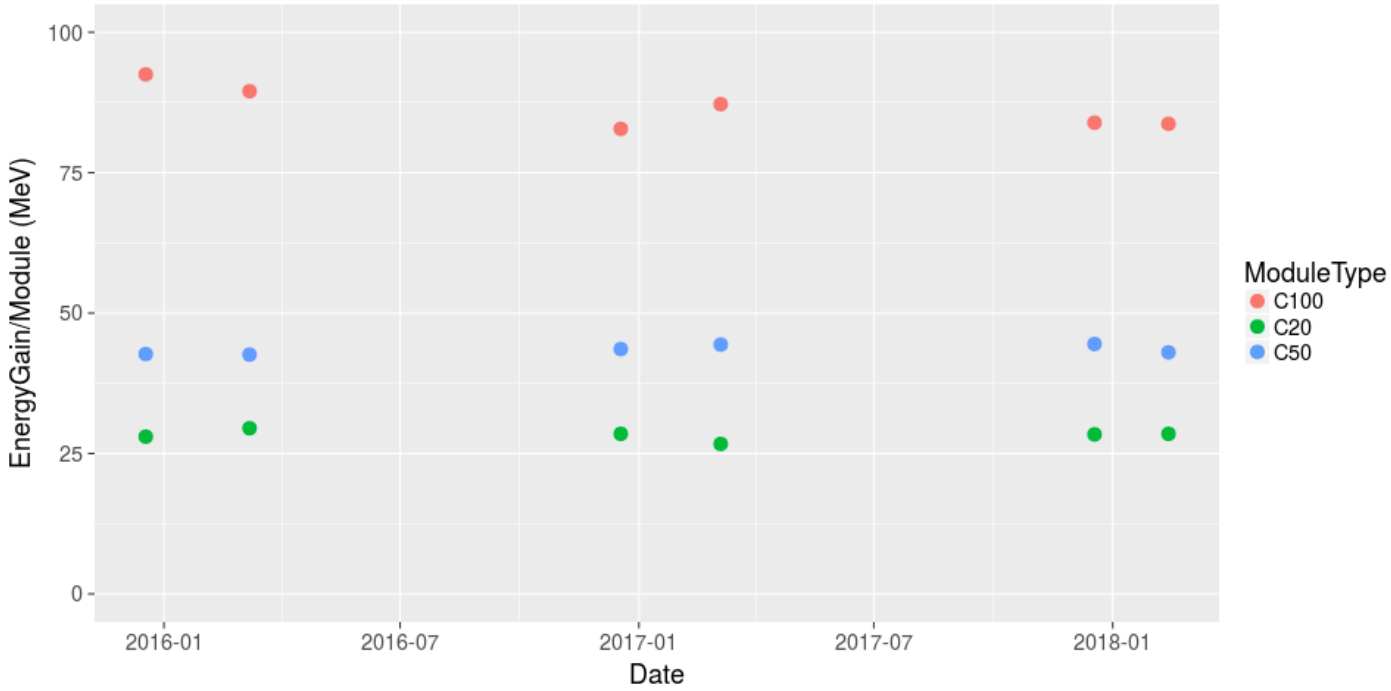
- Define the Performance Goals:
  - **Availability and Reliability**
  - Beam Parameters(ε, $\frac{\sigma_E}{E}$, σ_l, **beam energy**)
  - Peak Conditions (Hall multiplicity, operating weeks, ...)
- Perform gap analysis to identify where present CEBAF performance does not achieve the performance goals
- Develop a plan to close the gaps

CPP Goals with Identified Gaps

Category	Unit/Metric	Goal
Reliability	%	> 80
Optimal Weeks	weeks-per-year	37
Beam Tuning Hours	h/week	< 8
Peak Hall Multiplicity	Number of halls	4
12 GeV Program Expected Duration	years	20
Linac Design Energy	MeV	1090
Required Linac Energy Margin	MeV	> 110
Overall FSD Trip rate	trips/hour	< 15
Overall FSD Trip Downtime	min/hour	< 5
RF Trip rate	trips/hour	< 10
Beam Loss Trip rate	trips/hour	< 5

Table: The 12 GeV CEBAF Performance Goals with identified gaps.

CEBAF Cryomodule Performance



- CEBAF Energy set to 1090 MeV/linac in Fall2015, Spring2016
  - No gradient margin, CEBAF availability sub-par as each failed cavity must be recovered (versus by-pass)
- CEBAF Energy set to 1050 MeV/linac in Fall2016, Spring2017, Fall2017, Winter2018
  - Initially sufficient gradient margin ($\approx$ 50 MeV/linac) for Operations. Winter2018 lack of gradient margin ($<$ 30 MeV/linac) is impacting

CPP Energy Reach Plan

Energy Gap and Plan

Energy Gap

- CEBAF circa FY17/FY18 cannot support design energy.
  - CEBAF presently operates $\approx 4\%$ below design
- Historical loss, $\approx 34 MeV/pass/year$, exceeds the gains provided by refurbishing one C50/year.
  - Energy Reach gap is growing at ≈ 4.5 MeV/linac/year
  - Events like the CEBAF partial room temperature warm-up in Summer of 2017 increase the loss.
- Desire to close this gap as rapidly as possible to enable 12 GeV program at the design energy.

Energy Plan

C75 Upgrades Replace weakest CEBAF modules with a C75 module.

Warm Region Upgrades Clean warm region beamline vacuum regions and upgrade pumping technology

C100 Processing Continue investigation into the C100 under-performance. Including removal of a C100 for autopsy and refurbishment (to be determined).

CPP C75 Schedule circa June 2017

Date	FY	Proposed Linac Energy Setting for FY $\frac{\text{MeV}}{\text{linac}}$	Linac Margin $\frac{\text{MeV}}{\text{linac}}$	Rebuilt cryomodules completed in FY
2016-10-01	FY17	1050	55	C50-13
2017-10-01	FY18	1050	50	C75-1
2018-10-01	FY19	1050	56	C75-2
2019-10-01	FY20	1050	62	C75-3,C75-4
2020-10-01	FY21	1050	90	C75-5, C75-6
2021-10-01	FY22	1090	78	C75-7, C75-8
2022-10-01	FY23	1090	106	C100-Refurb-0
2023-10-01	FY24	1090	89	C75-9
2024-10-01	FY25	1090	95	C100-Refurb-1

This is no longer valid

50% of CEBAF warmed to room temperature Summer 2017 resulting in additional gradient loss and expected late arrival of C75-1 requires an updated schedule (next slide).

Adjusted Schedule: Feb 2018

	FY	Proposed Linac Energy Setting for FY	Linac Margin	Rebuilt cryomodules completed in FY	Comment
Date		$\frac{\text{MeV}}{\text{linac}}$	$\frac{\text{MeV}}{\text{linac}}$		
2016-10-01	FY17	1050	55	C50-13	Partial warm-up of CEBAF
2017-10-01	FY18	1050	25	F100, SL21	Install Two FEL hot modules
2018-10-01	FY19	1050	31	**C75-1**	**First C75 Installed Summer 2019**
2019-10-01	FY20	1050	37	**C75-2**/C100-Refurb-1	First C100 Refurbed module installed
2020-10-01	FY21	1050	50	**C75-3/C75-4**/C100-Refurb-2	**First year of two C75s**
2021-10-01	FY22	1090	36	**C75-5/C75-6**/C100-Refurb-3	
2022-10-01	FY23	1090	72	**C75-7/C75-8**/C100-Refurb-4	
2023-10-01	FY24	1090	108	C100-Refurb-5	
2024-10-01	FY25	1090	98	**C75-9**	
2025-10-01	FY26	1090	104	C100-Refurb-6	
2026-10-01	FY27	1090	94	**C75-10**	

2017 S&T and AAC Comments on C75/Energy Reach Plans

S&T Comments on the C75 and Energy Reach Plans

"I endorse the conservative approach to the choice of operational energy and the refurbishment of CM50s into CM75 as a path forward toward energy recovery.

"Beam energy management, as well as achievement of low trip rates, require high performance cryomodules. The C100 operational cavity gradients are lower than expectations. Over-performance in C20/C50 cavities has balanced the deficit resulting in a net -4% energy gap only. A failure or deterioration of a C100 cryomodule, or even more likely an old C20/C50 module, will reduce the available beam energy to below 12 GeV and increase the number of trips. The F100 in the Low Energy Recirculator Facility (LERF) can act as a hot spare in case of a failure. However, Jlab should consider options for a faster implementation plan to gain the desired 100 MeV margin per linac and to relax the constraints on the gradients. An additional C100 module and systematic reworking C50 cavities to C75 cavities by the SRF group can support this plan and will address the energy gap.

(LERF) can act as a hot spare in case of a failure. But building in 100 MeV of margin per linac can mitigate a whole module loss. The C100 operational cavity gradients are lower than expectations. Over-performance in CM20/CM50 cavities has balanced the deficit resulting in a net -4% energy gap. The current operational energy level reflects a conservative approach that includes margin for addressing emergent problems during run periods. Reworking CM50 cavities to C75 cavities by the SRF group will be used to address the energy gap at minimal additional cost. Particulates have been found on the

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accelerator division. Understanding and mitigating long-term gradient degradation is important to both CEBAF performance and future machine performance. Additional focus in this area is advised. JLAB should consider options for a faster implementation plan to gain the desired 100 MeV margin per linac (either an additional C100 cryomodule or the rework of C50 modules). The performance goals in terms of reliability and number of trips should be re-considered in the long-term and an improvement plan be considered.

Goals of this review

Charge

The C75 project represents a change in the CEBAF gradient maintenance program, requires significant lab resources and its success is a critical aspect of the CEBAF Performance Plan (CPP, JLAB-TN-17-022) as well as the Nuclear Physics 12 GeV program. The C75 project draws on the direct NP resources of the Accelerator and Engineering division, as well as indirect resources to support procurement for the project and any required changes in the power and cooling infrastructure.

This review is called by the Director of Accelerator Operations to address the charge elements listed below. The committee shall provide immediate assessment in the form of a verbal out-brief (with supporting presentation slides) at the conclusion of the review. A final written report is to be submitted to the Director of Accelerator Operations within two weeks of the review. This report will be public and will be distributed to the Laboratory Directorate as well as Accelerator and Engineering Division leadership.

Charge Elements

Charge 1: Does the proposed C75 system meet the requirements as defined in the CEBAF Performance Plan?

- Will the C75 module, RF controls and power deliver an integrated gradient of 70 MeV in GDR mode?
- Will the tunnel installation and commissioning of up to two C75 systems per FY allow for 37 weeks of CEBAF operation?
- Is the system design robust, reliable and maintainable? Is the proposed system consistent with a 20+ year 12 GeV CEBAF program?

Charge 2: Is the C75 system specification document complete?

- Are the cavity<->RF controls/power interface parameters clearly defined?

Charge 3: Are the resource requirements for the C75 system comprehensive and appropriately defined?

- SRF resources,
- Eng. resources,
- Facilities resources
- Operations resources (Software, commissioning support,. . .)

Charge 4: Have the project risks been identified and addressed?

Charge 5: Is the presented project organization and management appropriate?

- What additional controls if any should be implemented?

Today's Agenda

Agenda

Executive session (8:30 - 9:00)

- Closed

Introduction/Overview (9:00 - 10:05)

1. CEBAF Performance Plan (CPP): Energy Reach Focus (Arne)
2. CPP Implementation and Execution (Michaud)
3. C75 system specifications (Marhauser)
4. C75 Project Risk Assessment (Krafft)

C75 System Design (10:05 - 11:55)

1. Cavity (Marhauser)
2. Cryomodule (Gigi)
3. LLRF controls (Hovater)
4. RF Power (Nelson)

Executive Session/Lunch (11:55 - 13:00)

- Lunch Provided

C75 Schedule and Resources (13:00 - 15:00)

1. Cavities and Cryomodule (Reilly)
2. LLRF Controls (Hovater)
3. RF Power (Nelson)
4. Commissioning (Drury)

Executive Session (15:00 - 17:00) Preliminary Out Brief (17:00 - 17:15)

- Committee to verbally provide preliminary findings and questions for the C75 team.
- Discuss the path towards a final written report.

Adjourn (17:15)

Thank you

Committee Membership:

Charlie Reece	Chair, SRF R&D Deputy Dept Head
Rongli Geng	SRF R&D
Joe Preble	LCLS-II, Project Manager
Sarin Philip	Elec. Eng, DC Power Group leader
Ken Baggett	Elec. Eng, Ops Liaison
Matt Bickley	Deputy Operations Dept.

Preliminary Design Review Recommendations

2016 Preliminary Design Review Recommendations

1. A clear separation should be made between actions that are aimed at improving performance (better Q0) in both C50 or C75 cryomodules and those that are specific to the C75 module.

This was presented at the Jan 2016 debrief with Lab management. Slides can be made available.

2016 Preliminary Design Review Recommendations

2. A budget table should be produced that links expenditures to the proposed milestones in developing the C75 concept. The table should also address the out year annual expenditures, showing the planned C50 costs and the additional cost for the C75 program. The budget tables should separate procurements from JLab labor.

This was presented at the Jan. 2016 debrief with Lab Management. Slides can be made available.

2016 Preliminary Design Review Recommendations

3. Proceed aggressively with implementation of the C75 program as paced by available budget authority.

Within the restricted budgets in FY16 and FY17, the C75 design has progress to maturity. This includes the fabrication, assembly, commissioning and operation of two C75 cavities as part of the C50-13 cryomodule.

2016 Preliminary Design Review Recommendations

4. Prepare an analysis of and propose a C75-based program which would provide very satisfying availability for the physics program within three years and sustain it confidently thereafter.

The CEBAF Performance Plan (JLAB-TN-17-022) includes a plan to close the gap in the CEBAF energy reach. This plan includes the refurbishment of 8 C20 into C75 modules in the first five years of the plan.