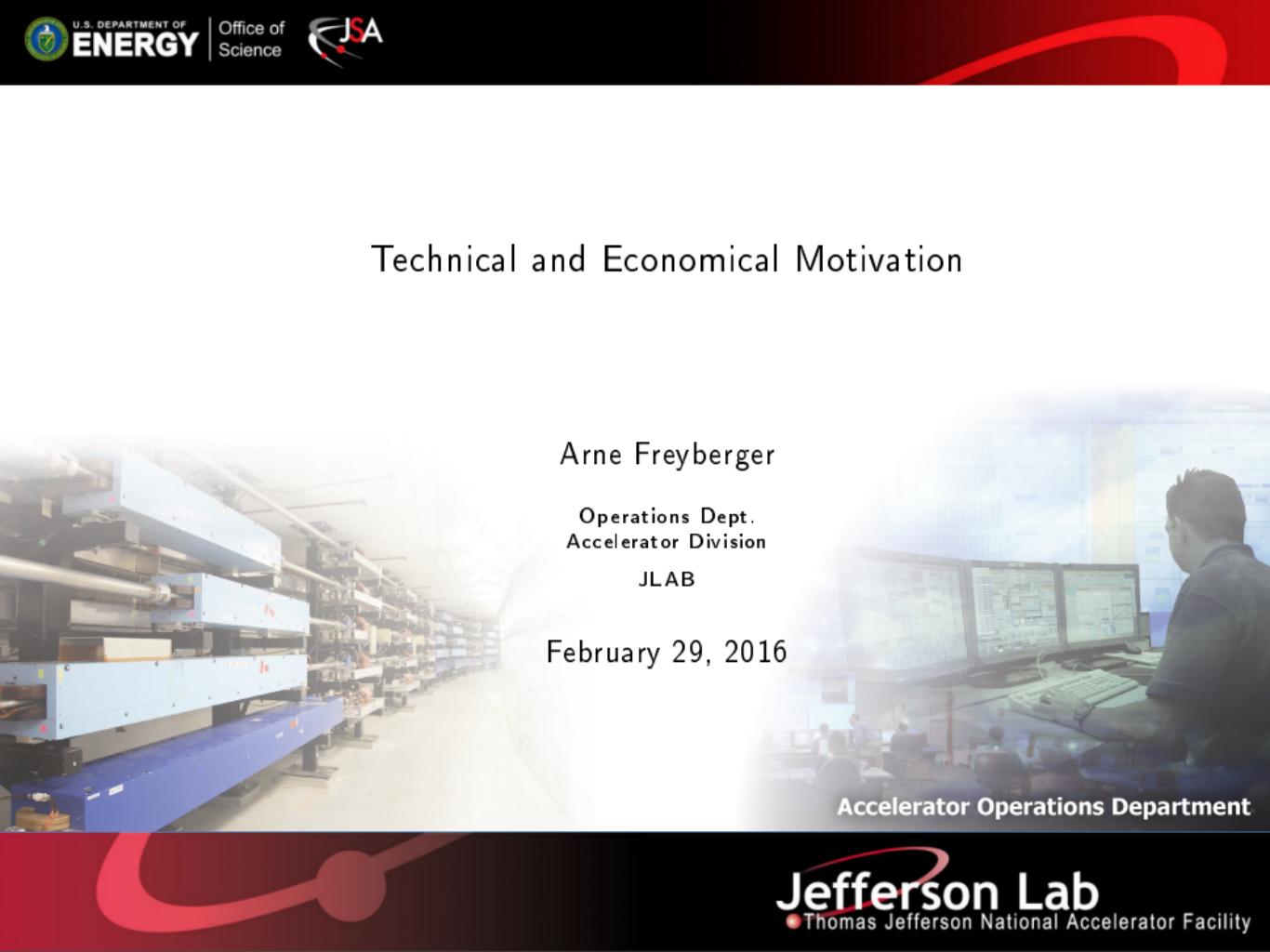


## Technical and Economical Motivation



Arne Freyberger

Operations Dept.  
Accelerator Division

JLAB

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Accelerator Operations Department

## 1 CEBAF Gradient Loss

- Historical C20/C50 Data
- CEBAF Energy Reach
- Gradient Degradation Cost

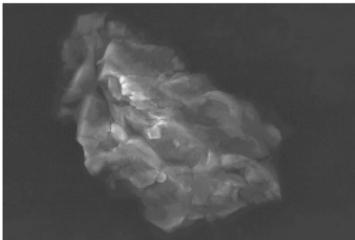
# CEBAF Gradient Degradation

- Annual gradient loss is about **34 MeV/pass-year**.
  - ▶ Loss rate is based on operations data since 1995.
- This value does not include any loss from the new C100 modules.
- Gradient gain from a C50 replacing a C20 module is less than 34 MeV:
  - ▶ **One C50/year is insufficient to maintain gradient.**

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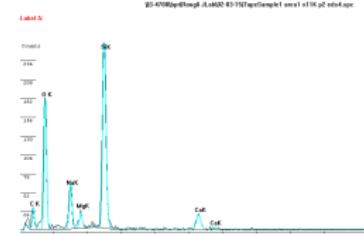
Cavity Type	$\frac{dG}{dt}$ (MV/m-yr)	$G_\Delta$ (MV/m-ThermalCycle)
C25	$0.14 \pm 0.05$	$0.5 \pm 0.1$ or 7%
C50	$0.42 \pm 0.06$	$0.5 \pm 0.1$ or 7%
C100	$0.00 \pm 0.06$	$0.5 \pm 0.1$ or 7%

Table 11: 2014 values of the average gradients and gradients loss for the various cavity types in CEBAF. All values are identical to the 2012 values except the C50  $\frac{dG}{dt}$  which was  $0.71 \pm 0.08$  MV/m-yr in 2012. The C100 annual loss remains at zero until there is enough data to provide an estimate of this loss.



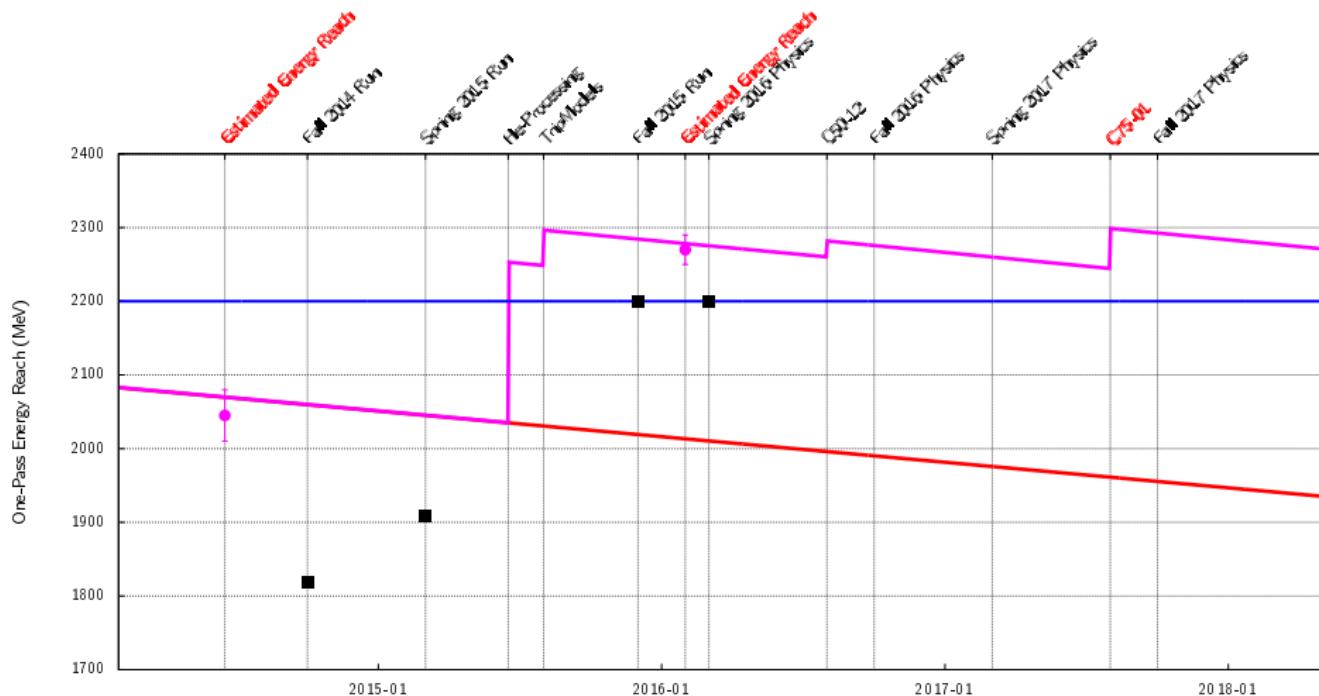
Example of particulate (Ca, Na, Mg, Si) found on the inner C20 surface before refurbishment.

CEBAF Particulate Field-Emitter Control



# CEBAF Energy Reach

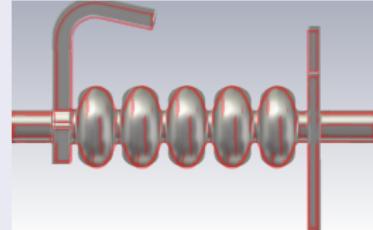
10 trips/h 1-pass Energy without Maintenance — Red  
10 trips/h 1-pass Energy with Maintenance — Magenta  
12 GeV setting — Blue



- Annual gradient gain must exceed the estimated gradient loss:
  - ▶  $E_{\text{gain}} > E_{\text{Loss}} + E_{C20}$
  - ▶  $E_{\text{gain}} > 34 \text{ MeV/year} + 30 \text{ MeV}$
  - ▶  $E_{\text{gain}} > 64 \text{ MeV/year}$
- The gradient gain must not be accompanied with a significant increase in the 2K heat load.
  - ▶  $\left(\frac{\mathcal{G}_{\text{new}}}{\mathcal{G}_{C20}}\right)^2 \approx \frac{\mathcal{Q}_{\text{new}}}{\mathcal{Q}_{C20}}$
- Must be able to transport at least 460  $\mu\text{A}$  CW beam.
  - ▶ RF Power and High Order Modes:

## The C75 Project

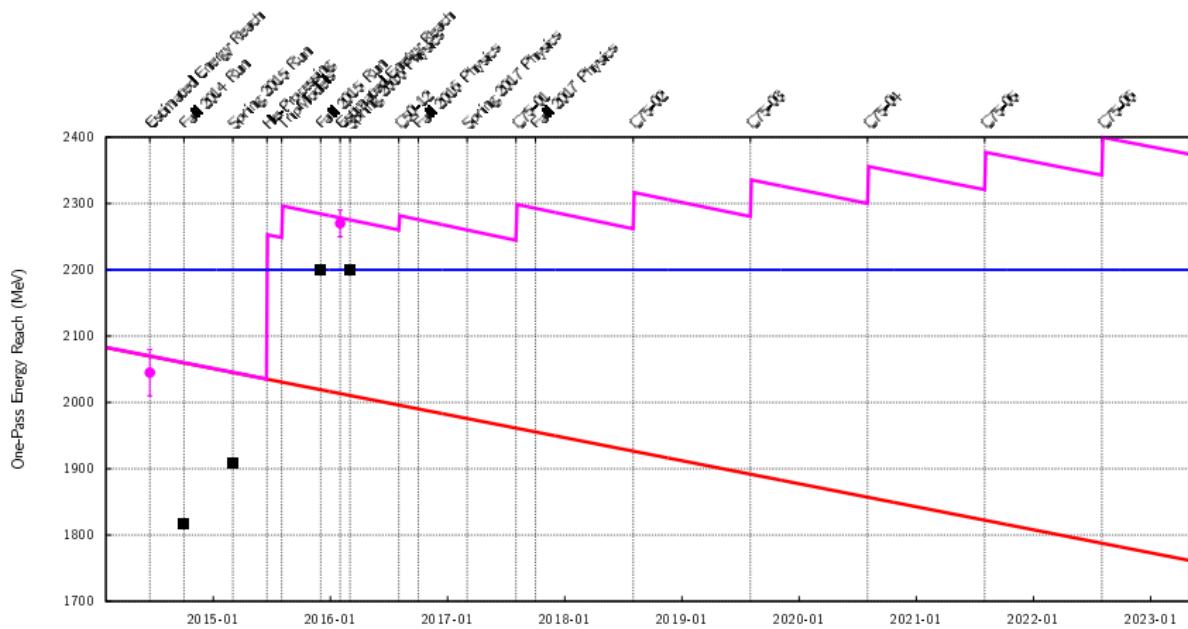
- Replace the original C20 cells (red) with the High Current cells(grey).
- Replace C20 analog controls with digital controls.
- Install 8kW klystrons (same form factor as 5kW C20 klystrons).



# C75 Long-term view

10 trips/h 1-pass Energy without Maintenance  
10 trips/h 1-pass Energy with Maintenance  
12GeV setting

Estimate Energy Reach (pink circle)  
CEBAF Energy (black square)



100 MeV/linac of margin achieved by 2022. Six C75 upgrades.

# C50-C75-C100 Cost Comparisons

Update - January 2016														
	# Cav	cells /cav	cav length m	Active Length m	fill factor %	MV	volts /cav (MV)	gradient (MV/m)	klystron power	unit cost (FY16 M\$ Direct)	*RF Cost	Total Cost FY16 Direct	MV (gain)	V(gain) /\$
C50	8	5	0.5	4	48.1	50	6.25	12.5	6	1.23	0.23	1.23	20	16.3
C75 <sup>†</sup>	8	5	0.5	4	48.1	75	9.4	18.8 <sup>‡</sup>	8	1.73	0.77	2.50	45	18.0
C100 <sup>‡</sup>	8	7	0.7	5.6	64.4	100	12.5	17.9 <sup>‡</sup>	13	4.30	1.56	5.85	70	12.0

<sup>†</sup>New cells or new processing required to achieve higher Q's and gradients

<sup>‡</sup>Digital LLRF required

- C75 18MV/M\$(direct)
- 34 MeV/pass/year

Cost just to keep CEBAF Energy reach constant (present status is 3% margin which has not resulted in robust operations).

Annual cost: 1.3 M\$/year (direct)

Lifetime cost (15y): 20M\$ (direct)

# CEBAF Energy Reach

10 trips/h 1-pass Energy without Maintenance  
10 trips/h 1-pass Energy with Maintenance  
12GeV setting  
Estimate Energy Reach  
CEBAF Energy  
C20 Reach

C20 Estimate Energy Reach  
C50/C75 Reach  
C50/C75 Estimate Energy Reach  
C100 Reach  
C100 Estimate Energy Reach

