



# Review on EP advances worldwide

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# Outline

- Introduction
- EP facilities in the world
- Recent achievement  
Horizontal EP / Vertical EP
- Summary



# Introduction

Now EP is applied on many projects as high reliable surface preparation.

It allows us to focus on other issues of cavity production.

We could find many progress on EP'ed cavity production.

Recent achievement is established not only by EP, but also with all other efforts on cavity production steps.

## Cavity production

- Fabrication
  - material
  - EBW
- Surface preparation
  - Bulk removal
    - BCP
    - EP
    - CBP
  - Degassing
  - Light removal
  - Baking
- Assembly
- Test



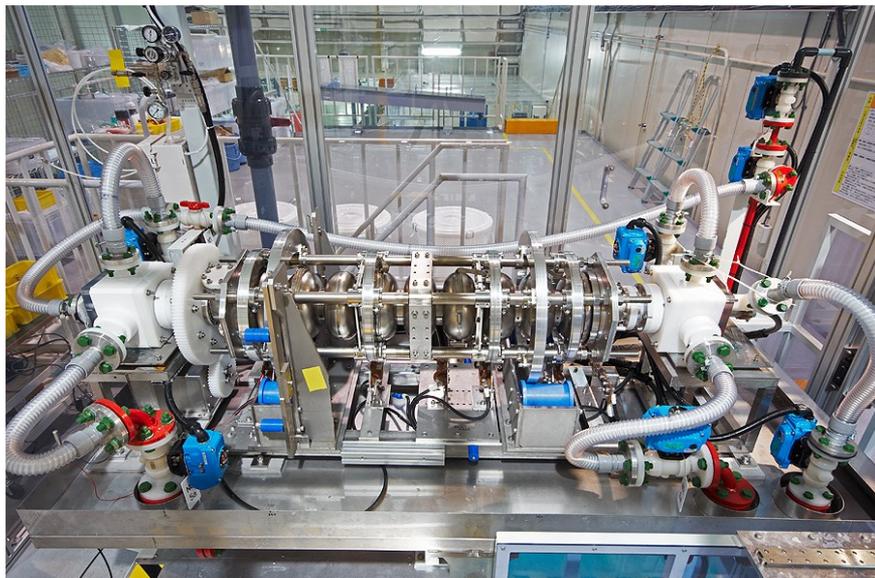
# EP facilities



# Horizontal or Vertical ?

Orientation	Facility
<b>Horizontal EP</b>	Asia: KEK STF Euro: DESY, ZANON, RI US: FNAL/ANL, Jlab
<b>Vertical EP</b>	Asia: KEK/Marui Euro: Saclay US: Cornell, Jlab

## No.1 EP Bed

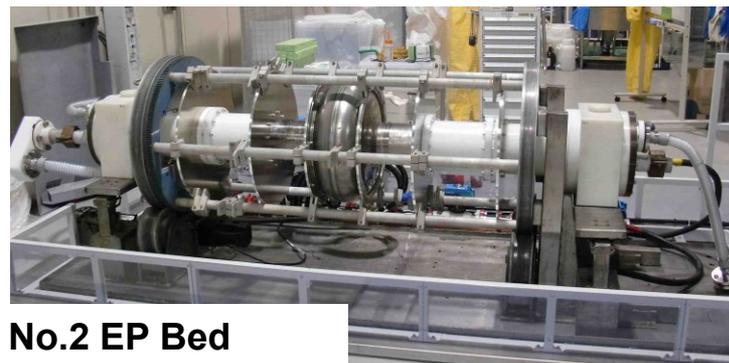


## No.2 EP Bed modified to fit ILC cavity

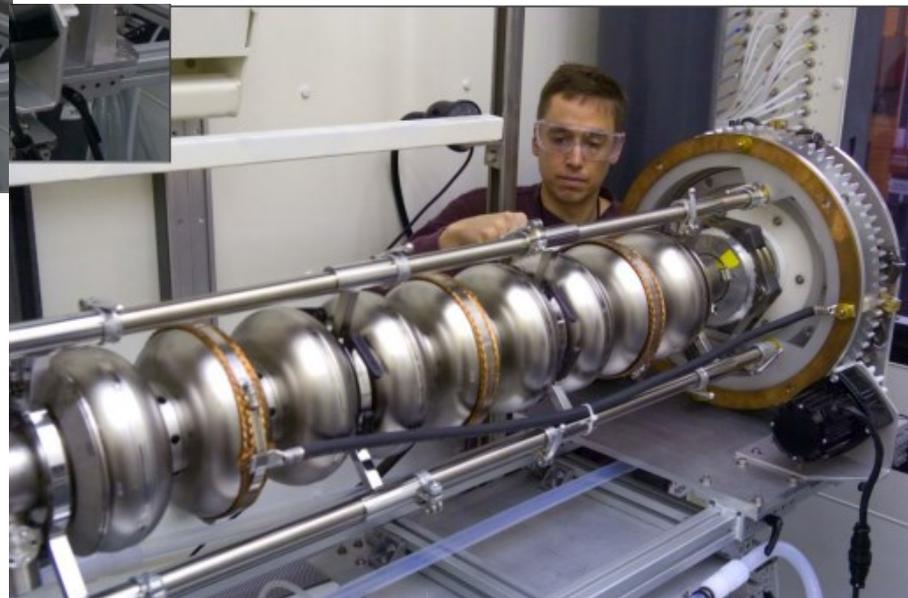
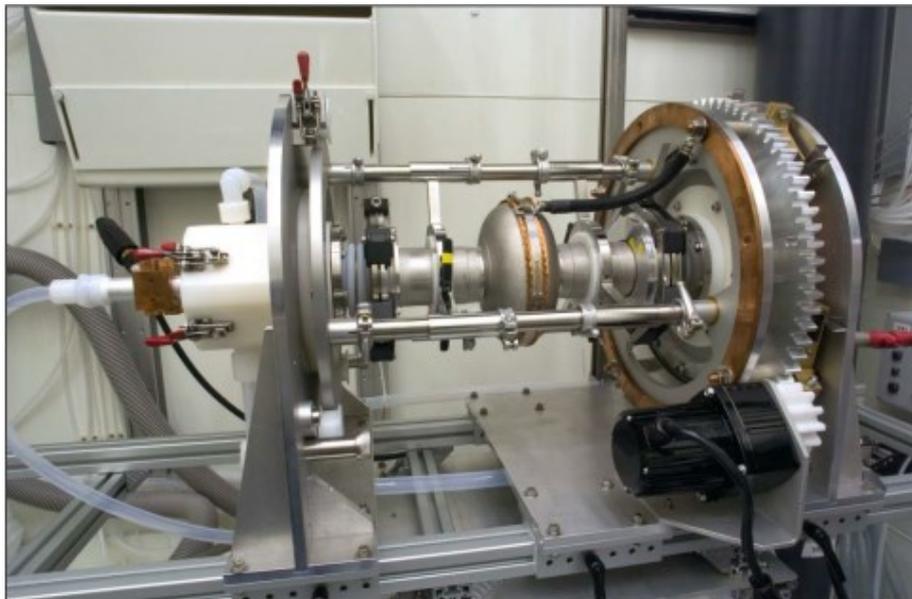


flow test using water

Presented by H. Hayano (KEK),  
cavity group meeting, 2012

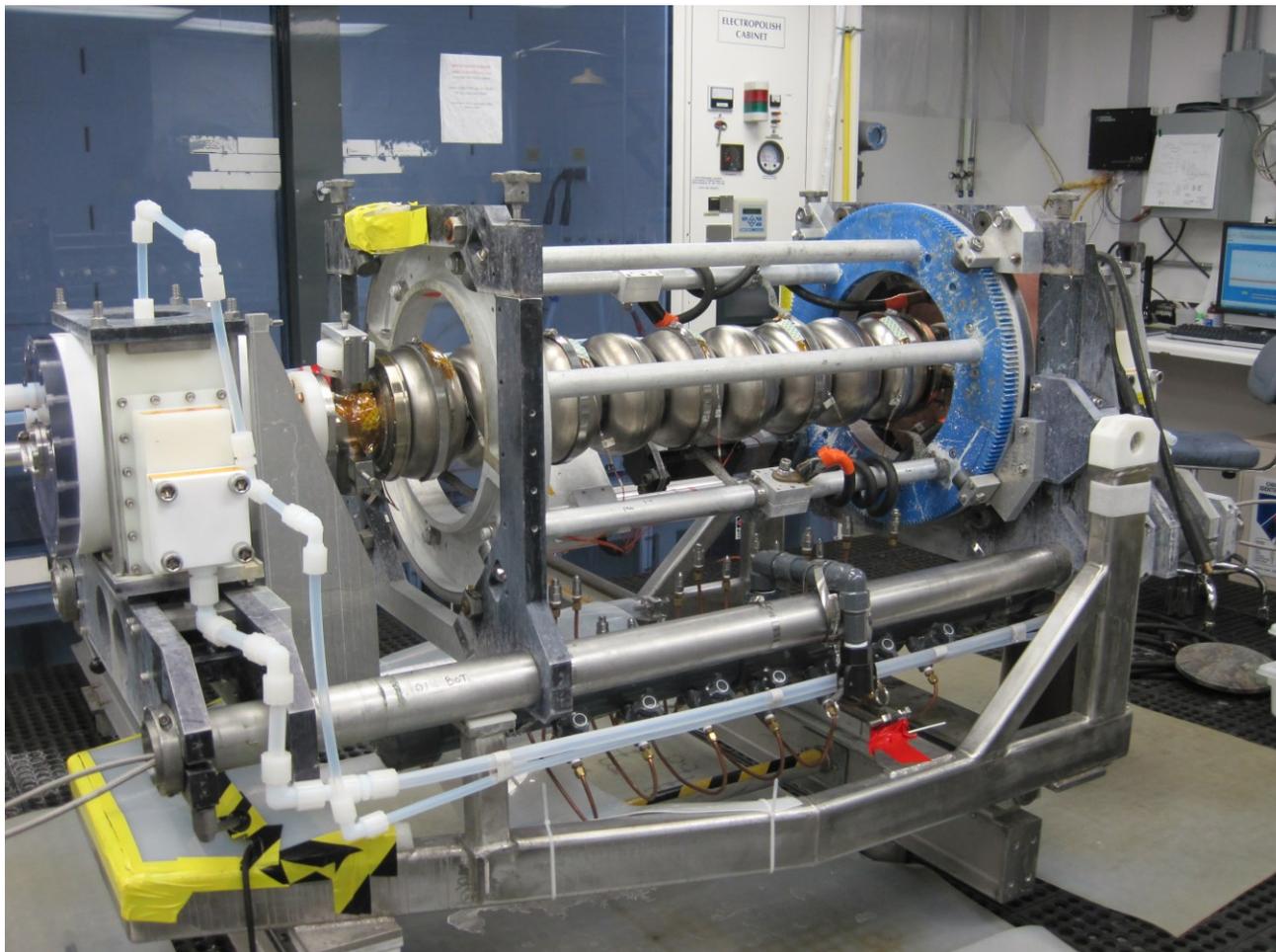


No.2 EP Bed  
for 500MHz cavity



**Presented by S. M. Gerbick (ANL) SRF2011, Chicago**

# Jlab, Horizontal EP

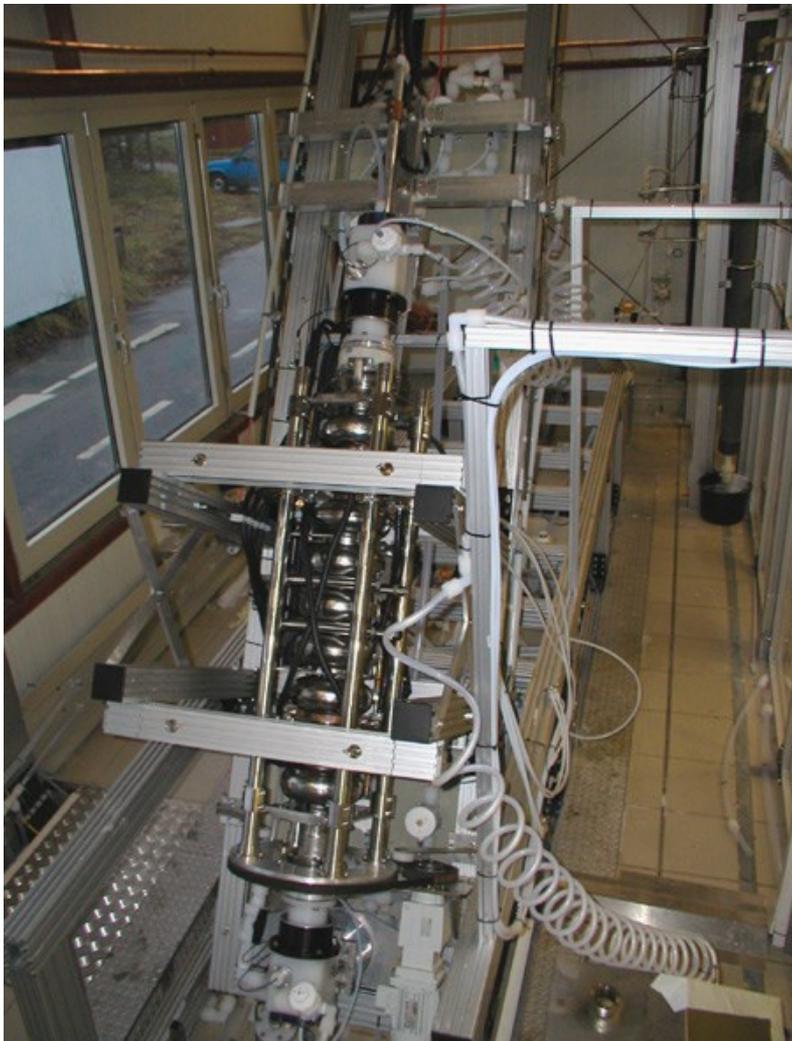




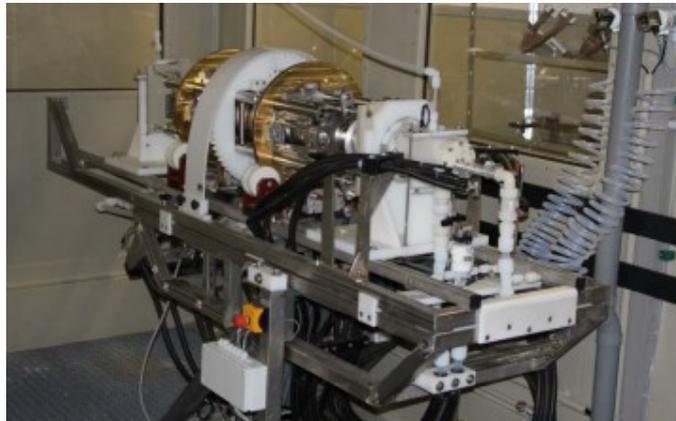
# for XFEL, Horizontal EP



## DESY



## RI



## ZANON



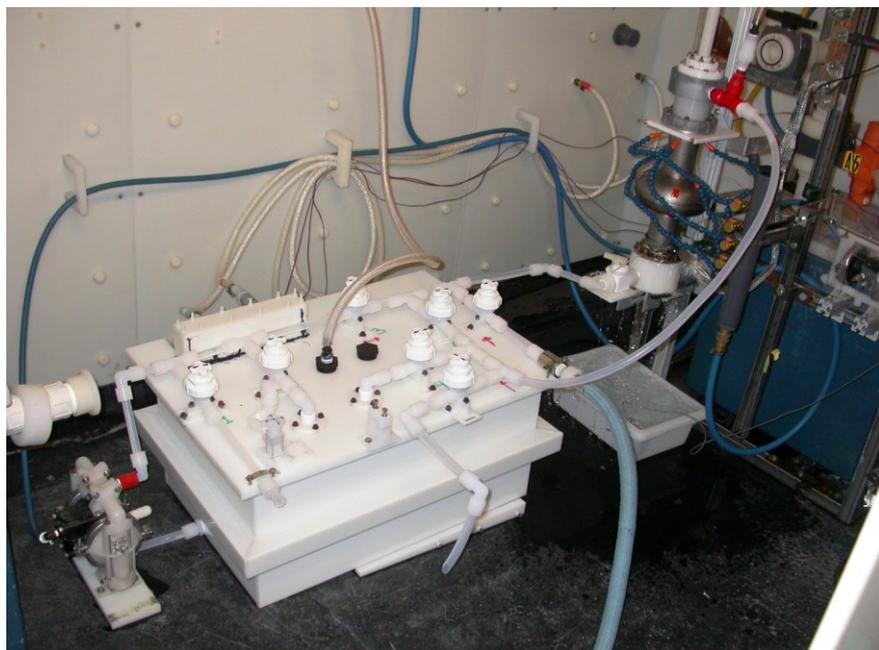
**Presented by W. Singer,  
ECFA LC2013, DESY**



**Presented by F. Eozénu, TTC meeting 2012,**



# Cornell, Vertical EP

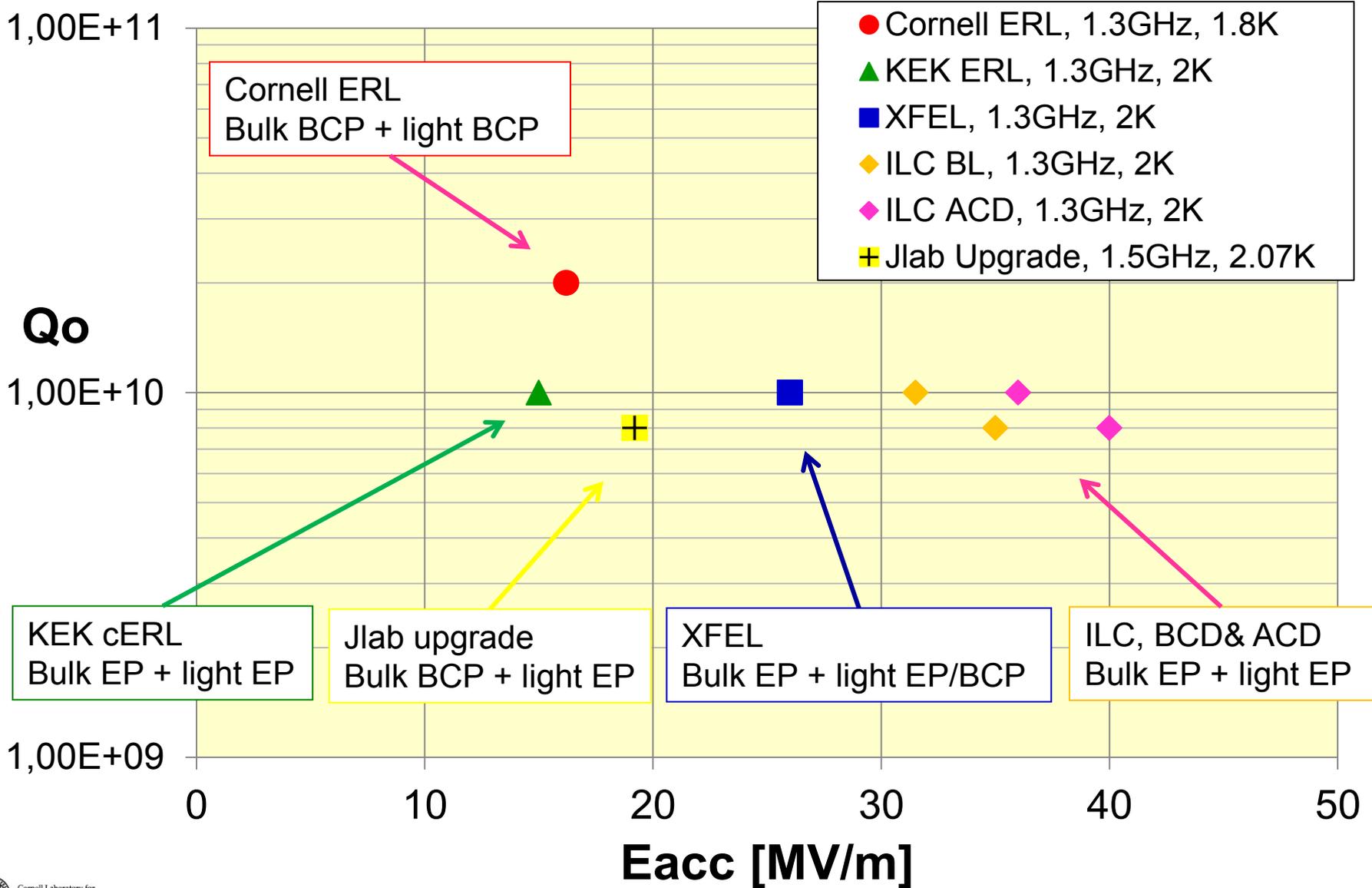




# Recent achievements w/ Horizontal EP



# Required cavity specs





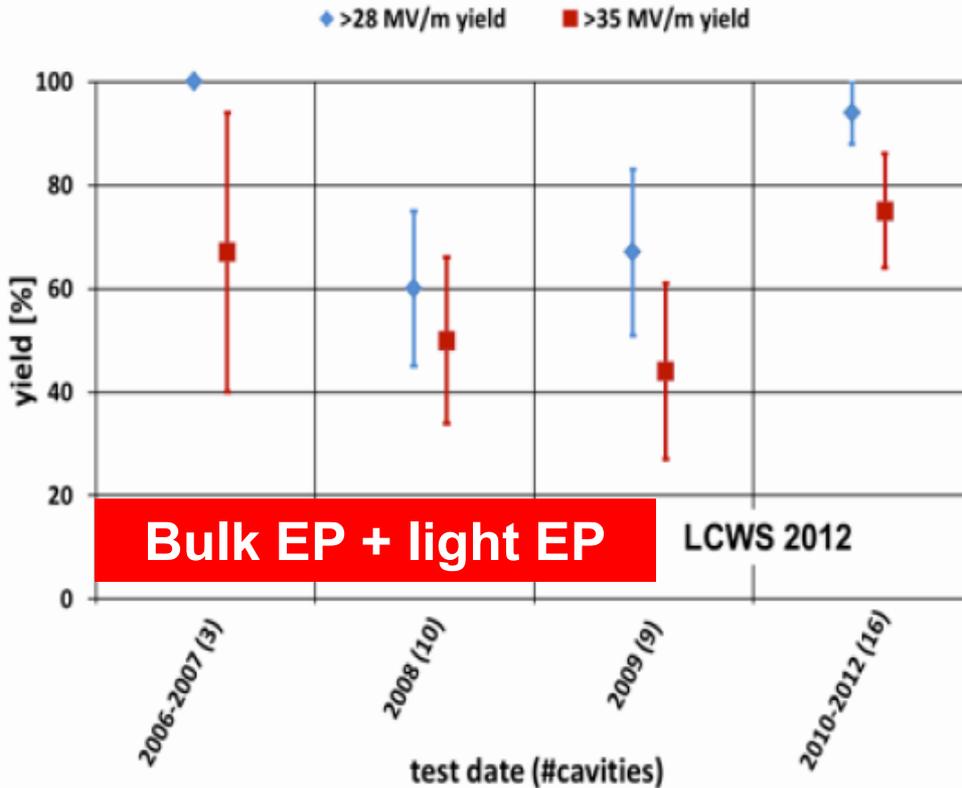
# Surface preparations

Project	Bulk removal	Degassing/ Annealing	Light removal	120C Bake	*Rinse
ILC	<b>EP</b>	800C*2hrs	<b>EP</b>	120C*48hrs	USC HPR
XFEL			<b>EP</b>		
			<b>BCP</b>		
Jlab 12GeV	<b>BCP</b>	600C*10hrs	<b>EP</b>	120C*24hrs	
Cornell ERL		650C*4days	<b>BCP</b>	120C*48hrs	HF rinse

On going R&Ds	CBP, VEP	High temp. process	VEP	Ar bake (145C*3hrs)	HF rinse Ethanol rinse
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# Progress in SCRF Cavity Gradient

2nd pass yield - established vendors, standard process



Production yield:  
94 % at > 28 MV/m,  
Average gradient:  
37.1 MV/m  
reached (2012)



# Jlab 12GeV, C100 SRF cavities



C100: string of **8 7-cell cavities**, **1497 MHz**, produced by RI (Research Instruments)  
**80 cavities** + 8 pre-production tested and assembled at JLAB

**18-step qualification process**

**EP derived from ILC R&D**



## Bulk BCP + light EP

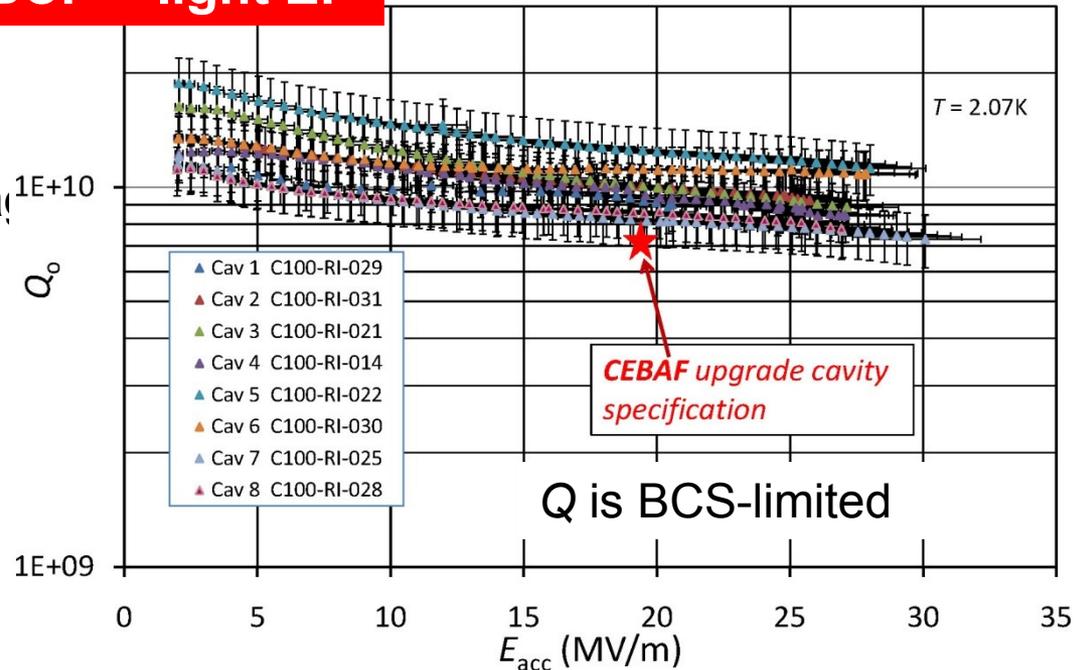
The cavity tests are performed at the Vertical Test Area (VTA)

Design gradient: **19.2 MV/m** average

Average heat/cavity: **29 W**

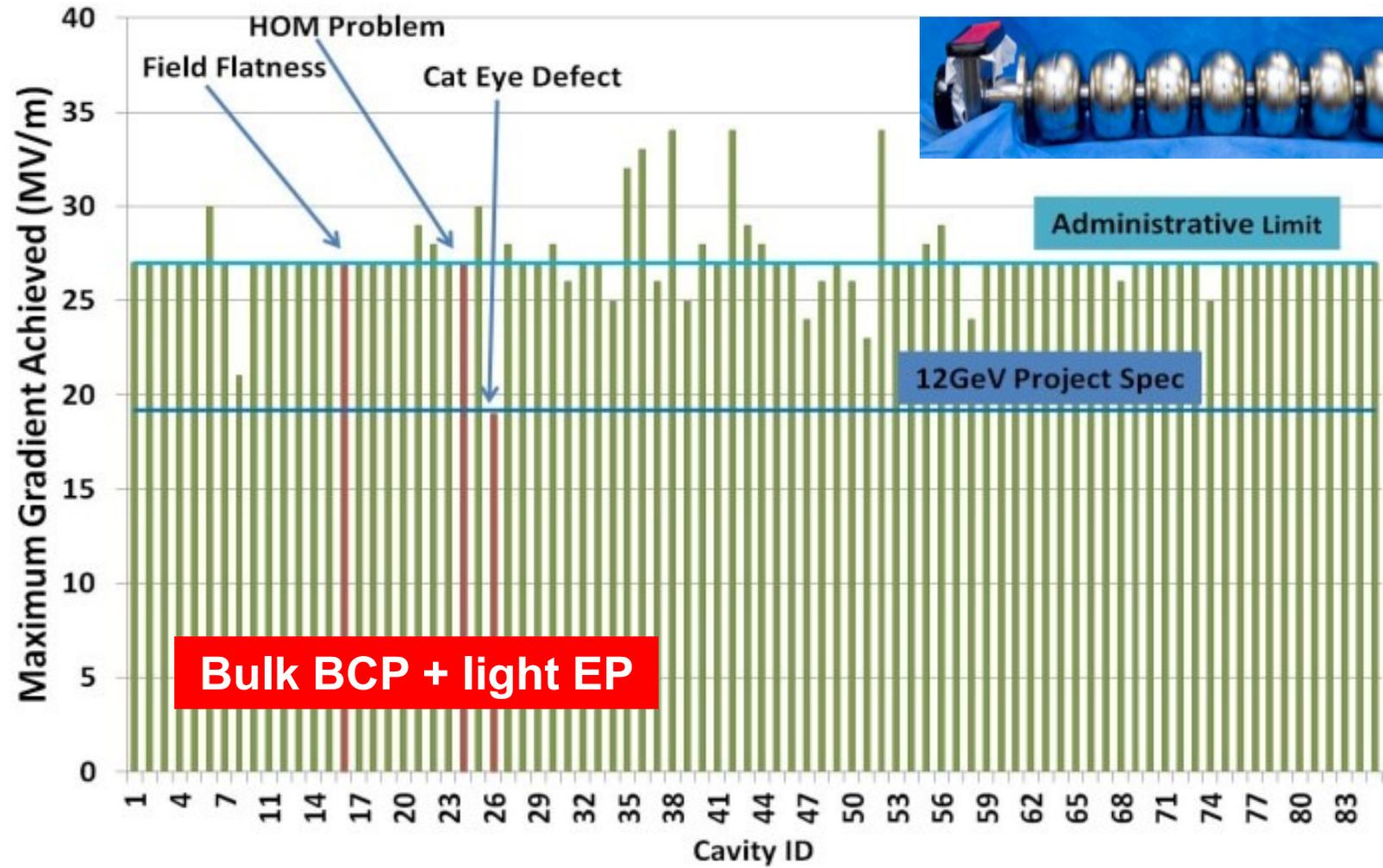
Operational limit: **25 MV/m**

(limited by the klystron RF power and possibly field emission)



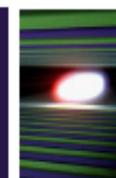
**Presented by F. Pilat, TTC2012, Jlab**

## Jefferson Lab 12 GeV C100 Cavity Final $E_{max}$

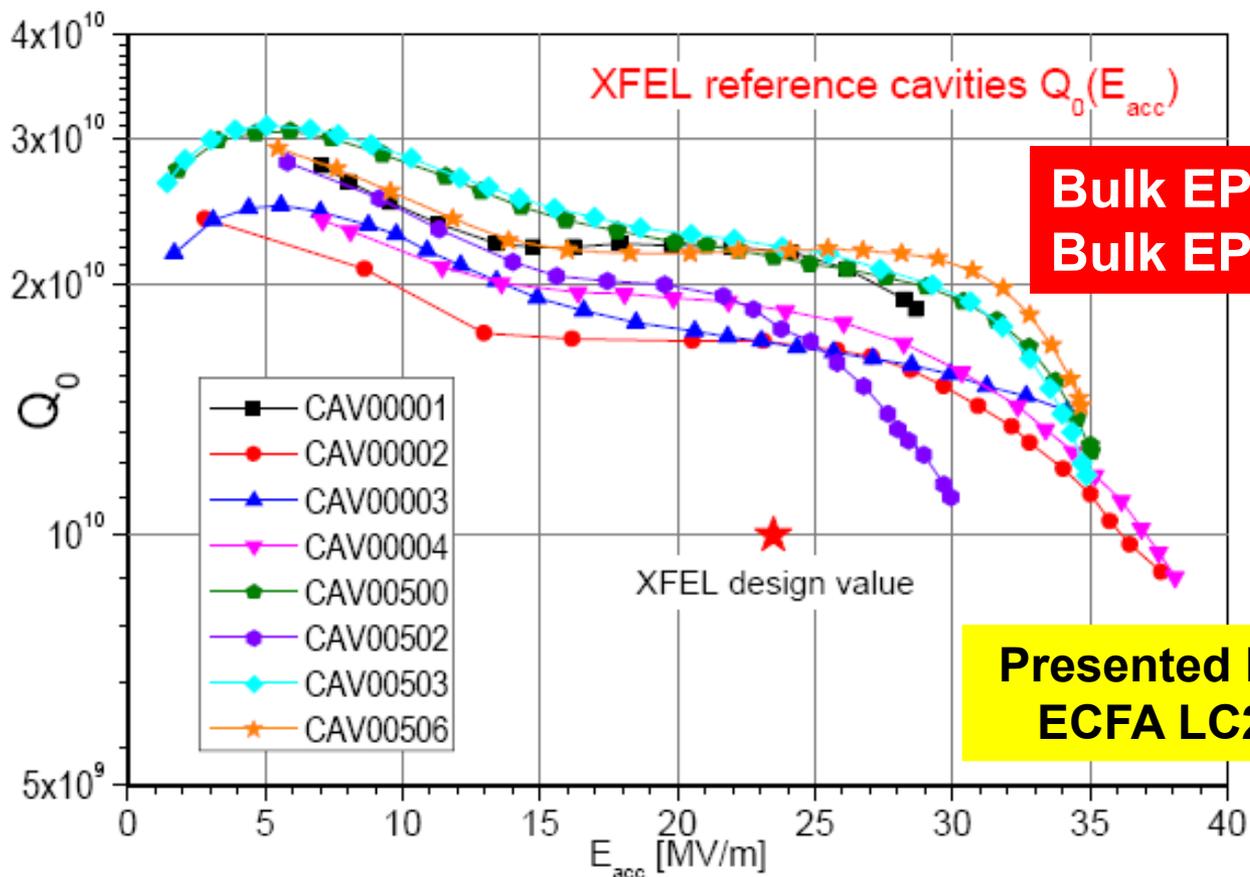


Presented by Fulvia Pilat, TTC2012, Jlab

# Performance of RCVs after treatment at DESY

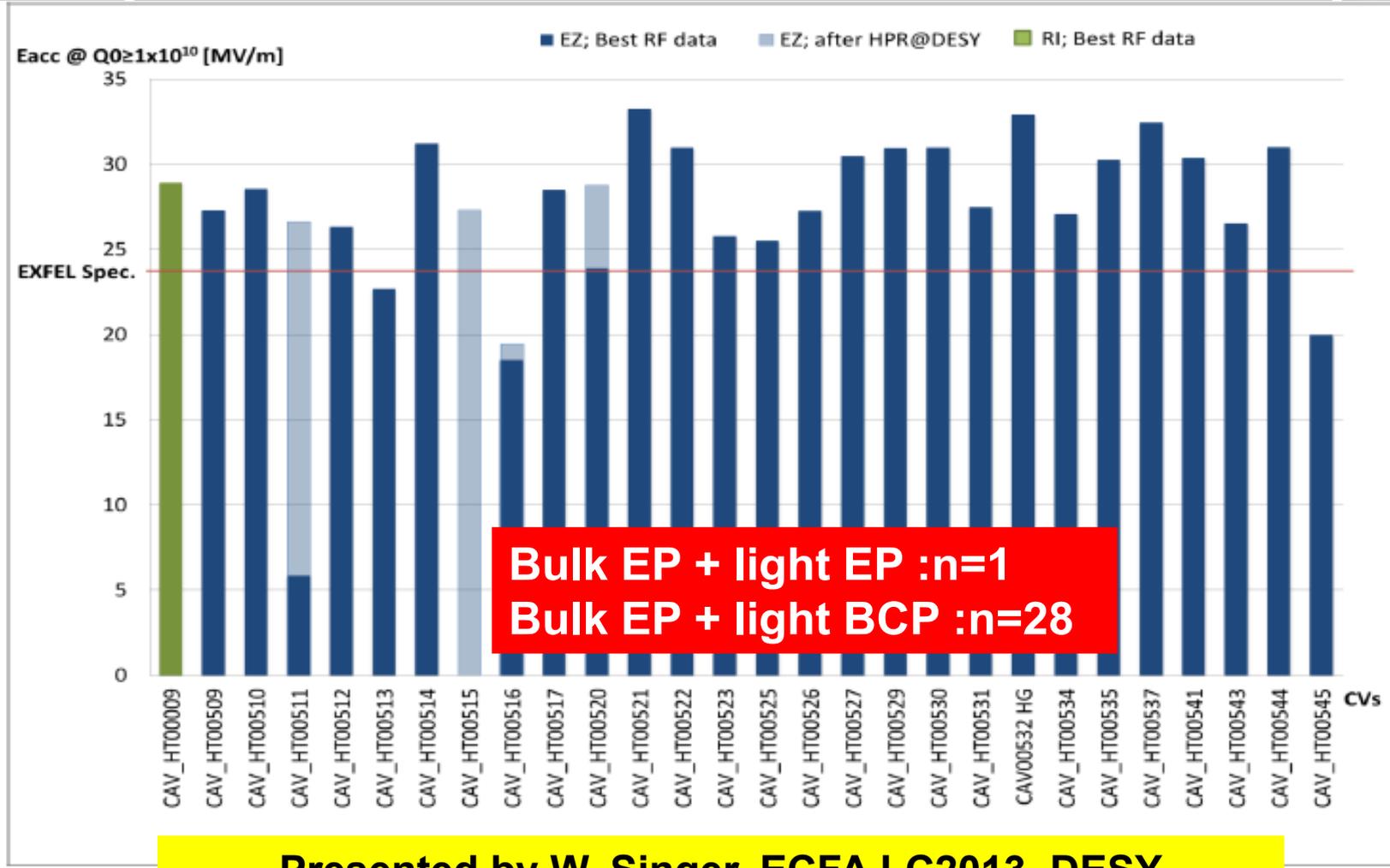
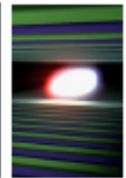


4 RCVs of RI and 4 RCVs of E. Zanon: acceptance test successful



Status of Cavity Production

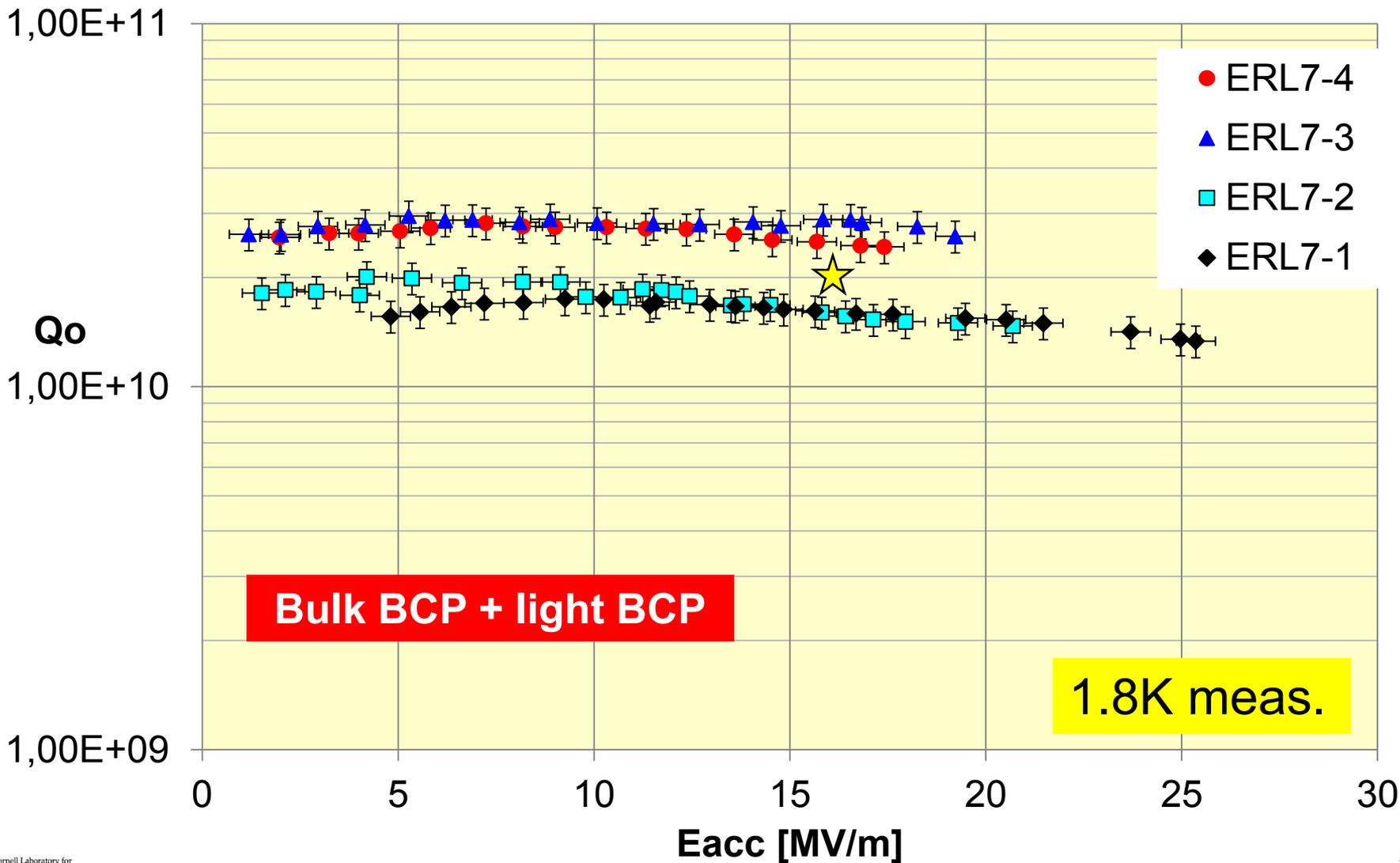
# Performance (status 24.05.13): $E_{acc}$ at $Q_0=1 \times 10^{10}$ (or max $E_{acc}$ for curves with $Q_0 > 1 \times 10^{10}$ )



**Presented by W. Singer, ECFA LC2013, DESY**

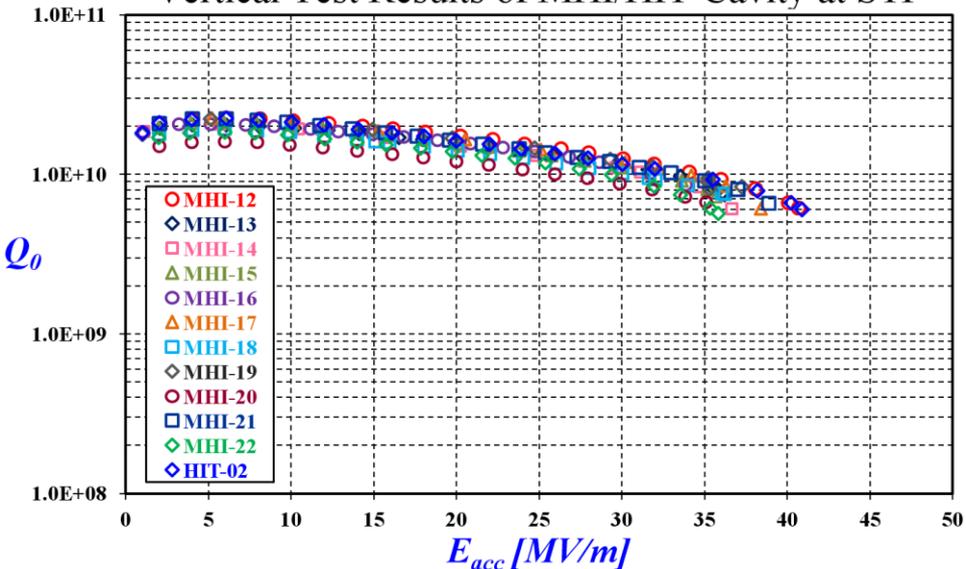
Industrial Cavity Fabrication and Treatment. ECFA LC 13, AC4, May 28, 2013. Waldemar Singer

## Cornell, VT results of ERL 7-cells

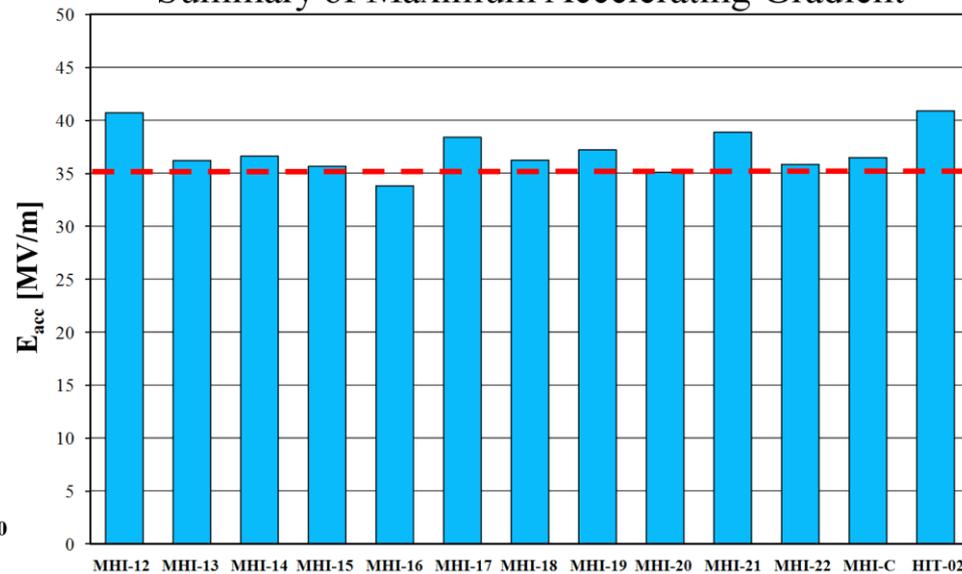


## Recent Results of V.T.

Vertical Test Results of MHI/HIT Cavity at STF



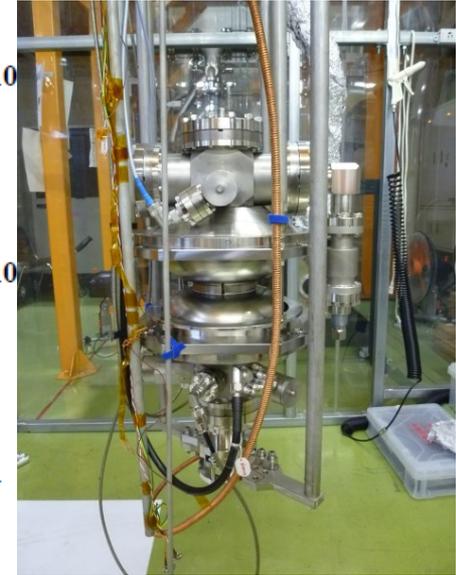
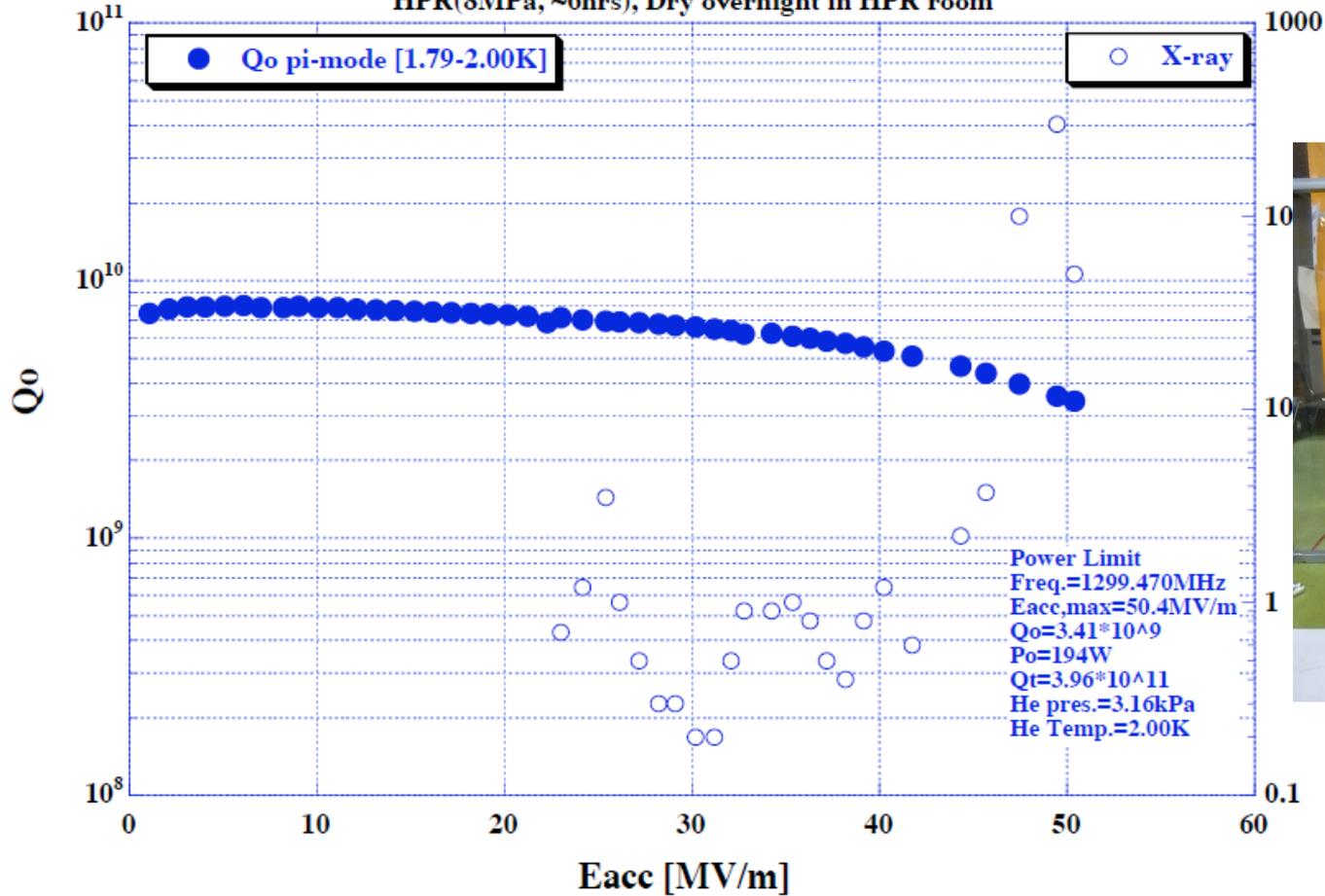
Summary of Maximum Accelerating Gradient



- ◆ Eight cavities for STF-2 reached above 35 MV/m.
- ◆ HIT-02 reached around 41 MV/m.
- ◆ MHI-C reached around 36 MV/m.

Presented by Kirk Yamamoto  
LCC cavity Group Meeting 16/Apr/2013

ERL 2cell Cavity #2 5th. V.T. Mar.06, 2012  
 [With Five HOM Pickup Antennas; Type-II(male pin)]  
 EP-II(5 $\mu$ m), Water flow(1.5hrs), FM\_20 2%(50C,30min),  
 HPR(8MPa, ~6hrs), Dry overnight in HPR room

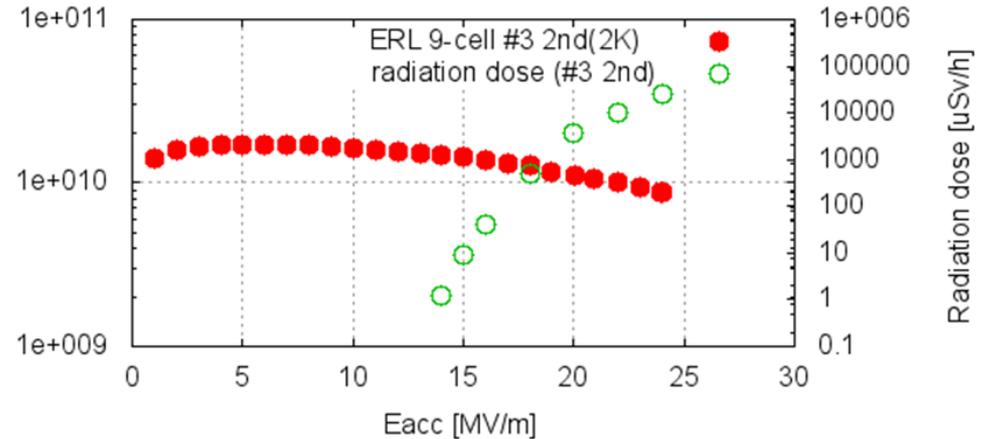


**Presented by K. Watanabe (KEK) May/2012**

Two 9-cell cavities were fabricated for cERL and vertical tests were performed two times for each cavity. (followings are results for 2nd tests) **by K. Umemori**

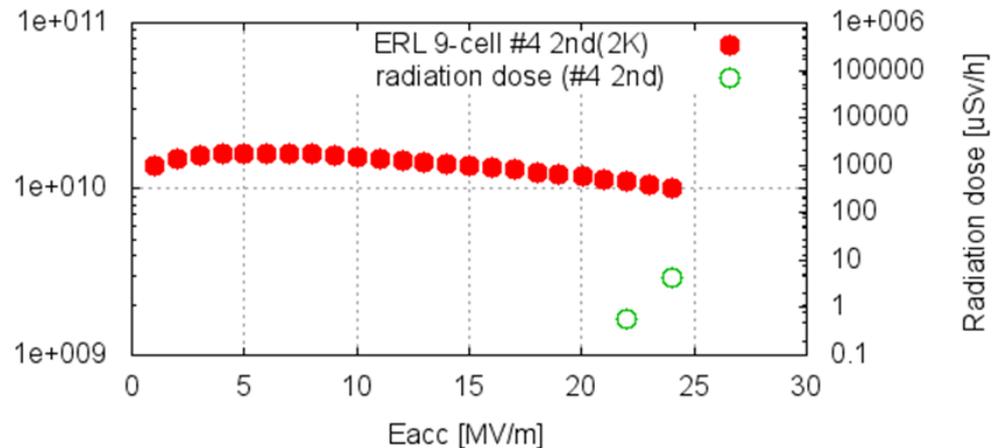
## ERL 9-cell #3 cavity

- Field reached to 25 MV/m
- No limitation up to 25 MV/m
- $Q > 1e10@15MV/m$
- Satisfied cERL specification
- X-ray onset around 14 MV/m



## ERL 9-cell #4 cavity

- Field reached to 25 MV/m
- No limitation up to 25 MV/m
- $Q > 1e10@15MV/m$
- Satisfied cERL specification
- X-ray onset around 22 MV/m



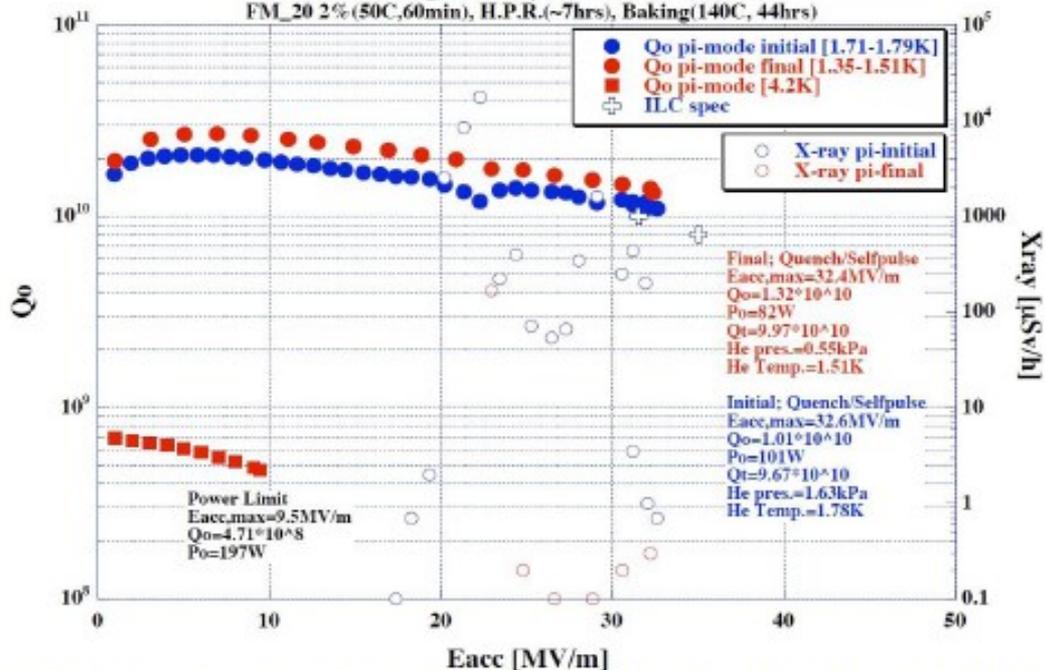
Presented by E. Kako (KEK), TTC meeting 2012, Jlab

## PKU/KEK collaboration



- Test01 at KEK
  - EP 120  $\mu\text{m}$ , HT 750  $^\circ\text{C}$  3 hr
  - EP 5 $\mu\text{m}$ , baking 140  $^\circ\text{C}$  48 hr
  - Eacc 23.8 MV/m,  $Q_0=6.9\text{E}9@E_{\text{max}}$
- Test02 at KEK, after local grinding

PKU No.04(Large Grain; TESLA Shape) 2nd. Vertical Test 04/25/2013  
 Local Grinding, EP-II(20 $\mu\text{m}$ ), Water flow(1.5hrs),  
 FM\_20 2%(50C,60min), H.P.R.(~7hrs), Baking(140C, 44hrs)



Latest test April 25, 2013  
 PKU4 achieved 33 MV/m  
 At  $Q_0$  1E10 at 1.8K

Further processing and testing including local grinding under way

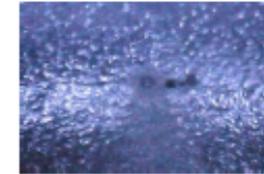
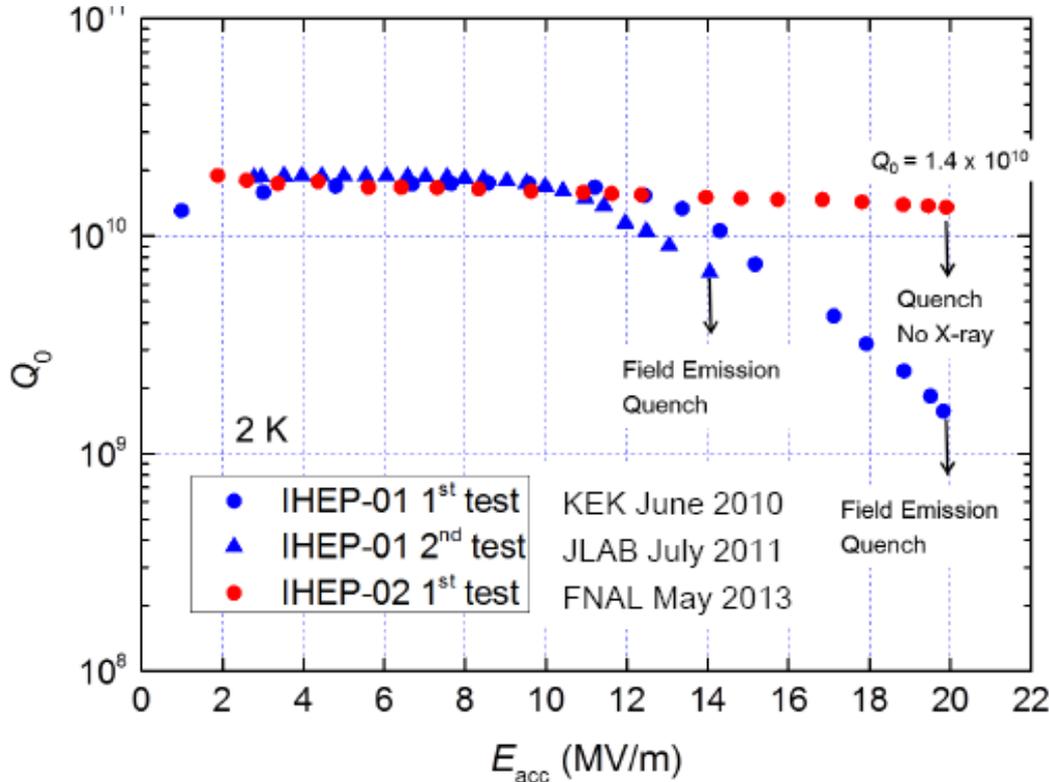
Courtesy Jiankui Hao, PKU



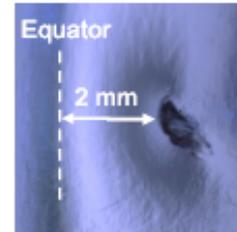
# 9-cell Test Results and Limitation

IHEP/KEK, Jlab, FNAL collaboration

Courtesy Jiyuan Zhai, IHEP



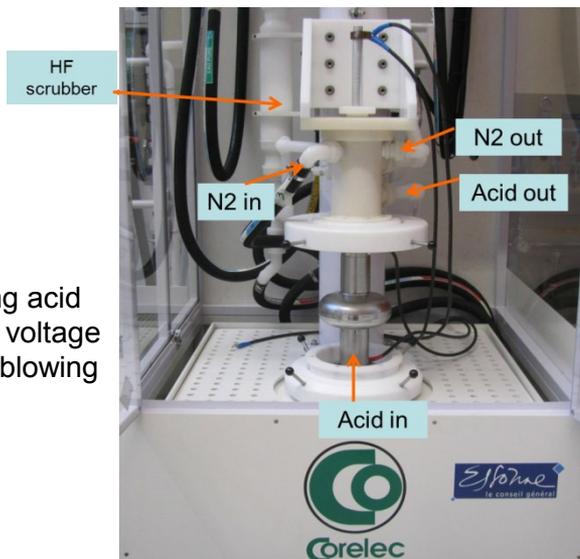
A pit on the iris and possible contamination may be the reason of strong field emission of IHEP-01.



IHEP-02 quench defect (detected by second sound and thermometry). The quench location has sharp and deep grain boundary step made during half cell pressing.

By passband mode test, 5 cells of IHEP-01  $\geq 30$  MV/m, 7 cells of IHEP-02  $\geq 40$  MV/m, both Pi modes quench at 20 MV/m in cell#9 300 deg equator.

# Recent achievements w/ Vertical EP



- Circulating acid
- Constant voltage
- Nitrogen blowing



Fermilab  
TB9RI025 cavity  
Prior to VEP

- VEP of 1Cell and 9Cell cavities
- Focus on parameters: low voltage ( $\sim 6V$ ) – high acid flow (25L/min)
  - Improved degassing ( $H_2$ ,  $O_2$ )
  - Lower heating
- Four 1-Cell cavities and 1 nine-cell cavity prepared by VEP
- But delay in results: Field Emission problems (cleanroom's water)

**Presented by F. Eozénou, 1<sup>st</sup> LCC/ILC cavity group meeting, 2013**

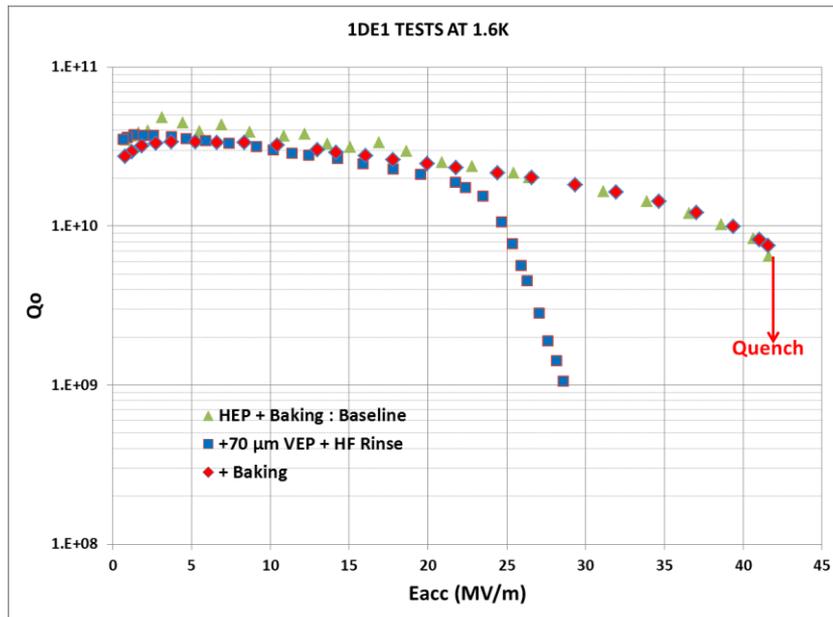


## 1DE1: Horizontal EP + 70 $\mu\text{m}$ VEP

- Parameters: 6V & >24L/min
- Bright and smooth surface
- Performance before/after baking similar to HEP
- High gradient maintained after VEP



1DE1 after HEP + 70  $\mu\text{m}$  VEP



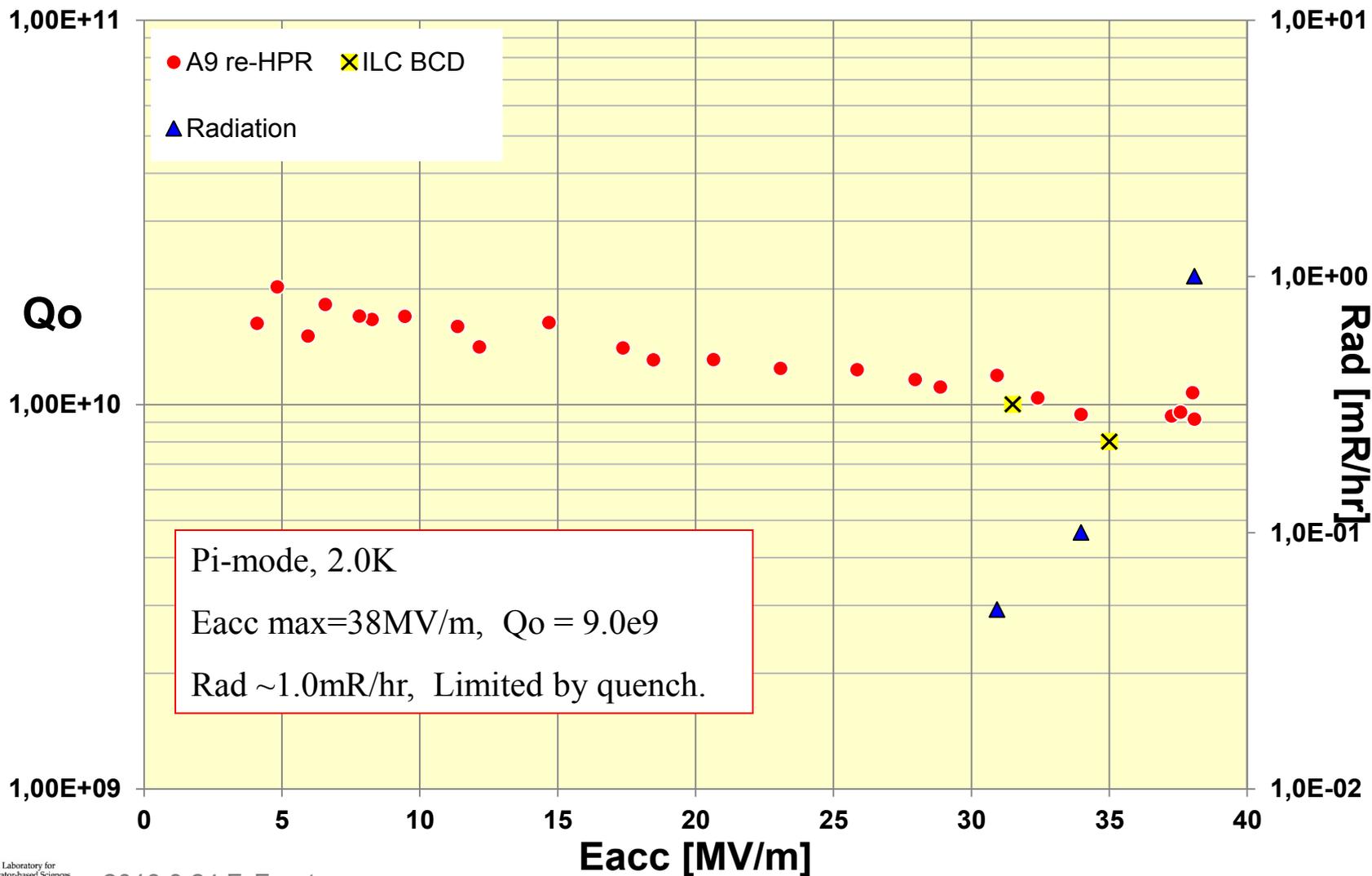
Aspects to improve:

- Low removal rate at 19° C: 0.2 $\mu\text{m}/\text{min}$
- asymmetry: removal rate higher in the upper part of the cell (x 3)

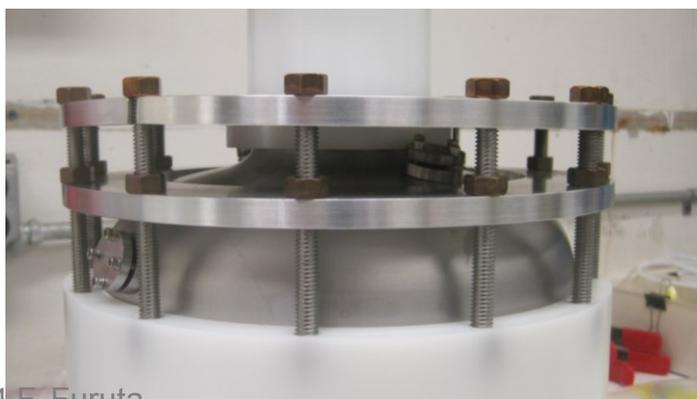
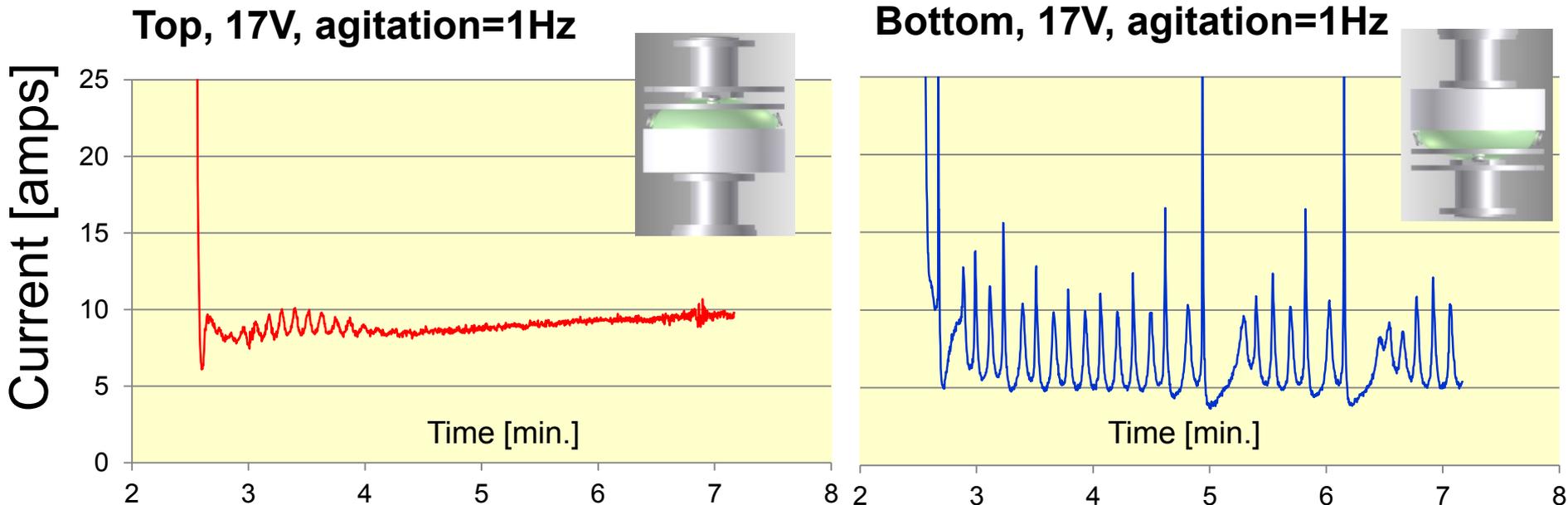


**Presented by F. Eozénou, 1<sup>st</sup> LCC/ILC cavity group meeting, 2013**

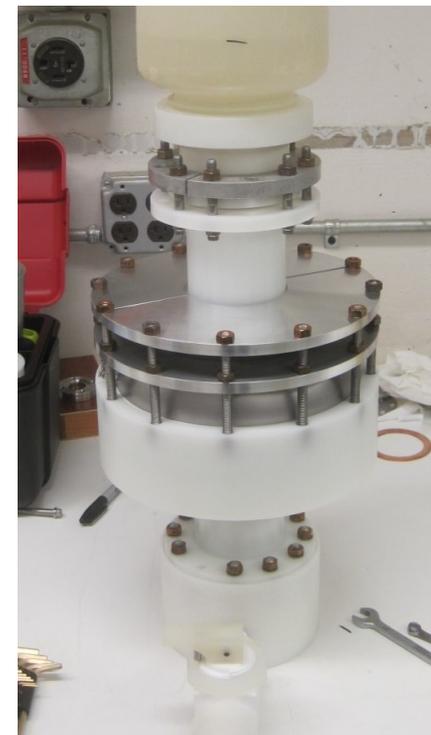
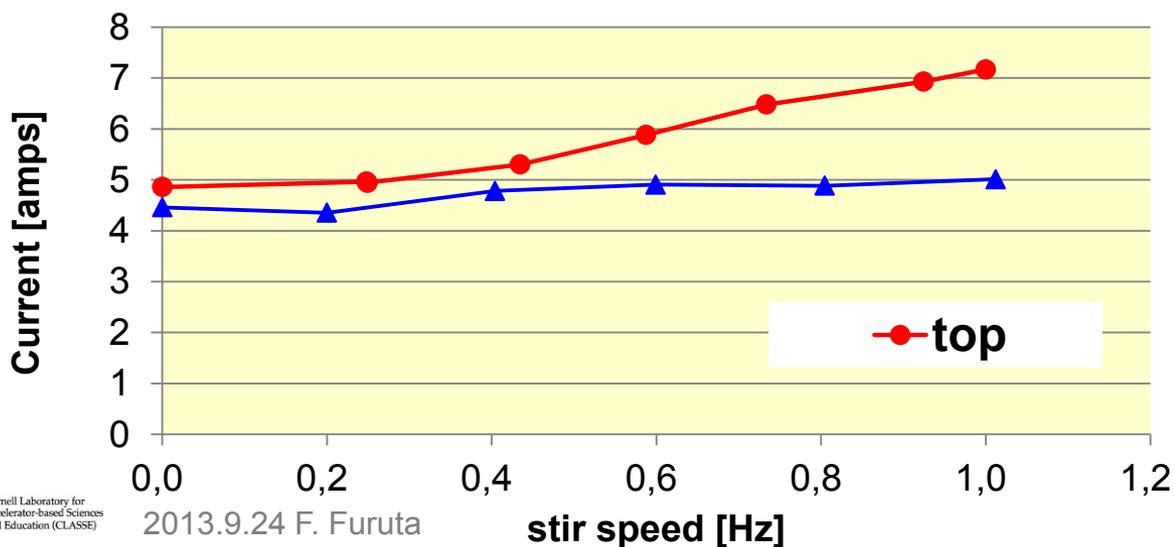
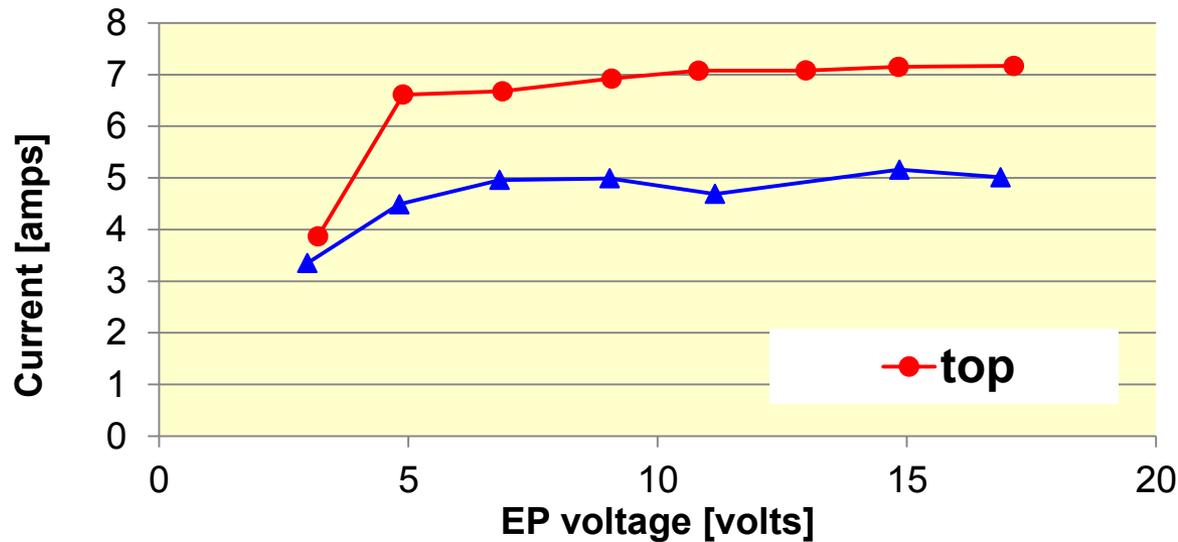
## 1<sup>st</sup> achievement of 40MV/m w/ VEP + TESLA 9-cell



## Results of half cell VEP, Comparison of top & bottom



## Half cell VEP, I-V curve, stir speed dependence





# Summary

- EP based surface preparations have successfully achieved design specs with high yield in various project.
- This means the reliability of EP facility and cavity production procedures are also very high.
- Reliable EP facilities are also available for qualification of new cavity manufacturing. Collaboration on surface process and VT become more strong.
- Based on high reliability of EP, we could focus on other parts of surface processes to improve or cure cavity performance.

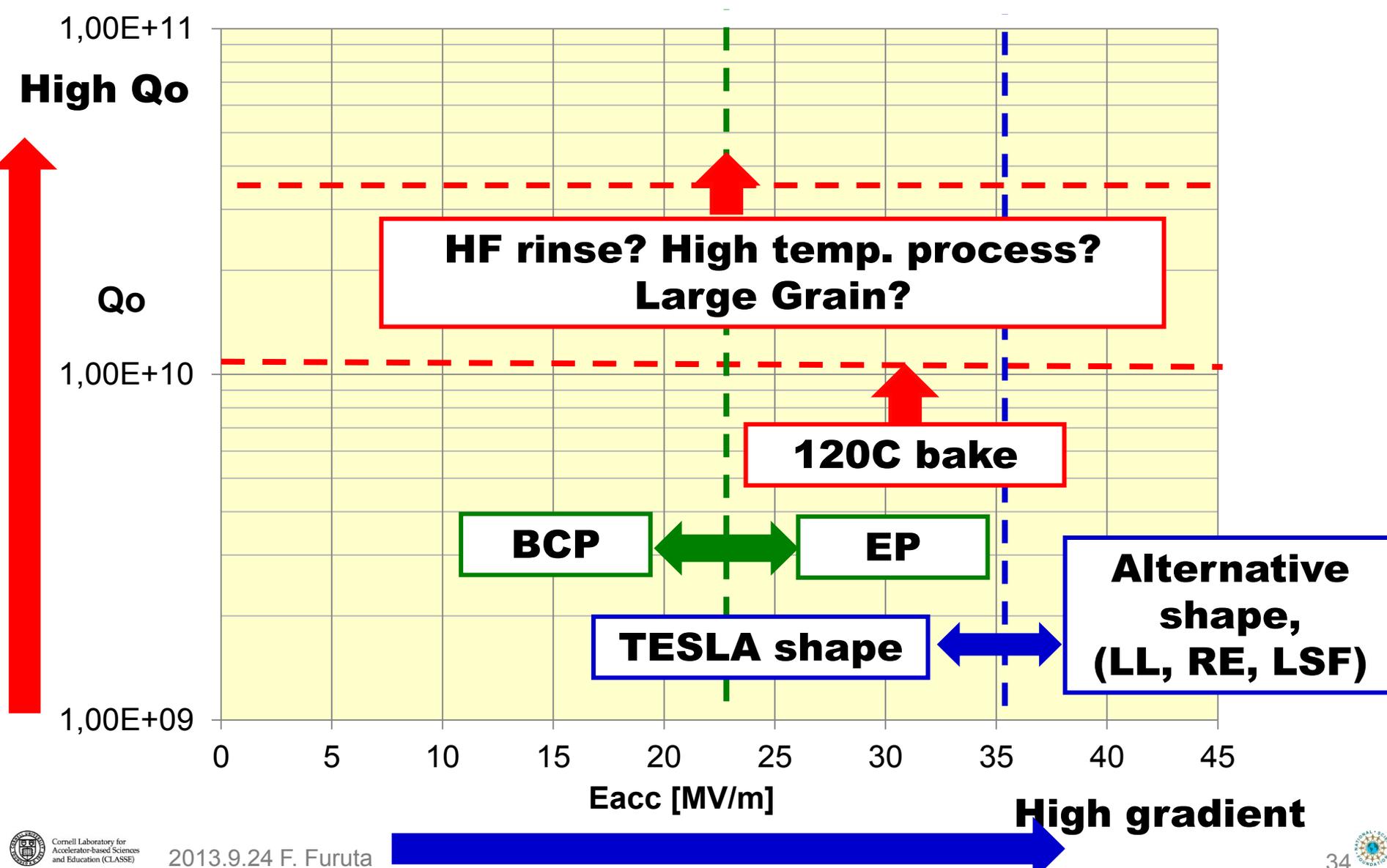


# Summary

- VEP'ed cavities have successfully achieved high gradient with high  $Q_0$ . Demonstration of VEP capability are done.
- R&Ds on VEP parameter optimization are on going. Next high priority is demonstration of high yield with VEP.
- Many VEP facilities are now available, more close communication, discussion, and collaborations are expected.



# What is the best surface treatment?





# Today's posters related to EP



- TUP046, F. Eozénou (Saclay) et al.
- TUP047, L.M.A. Ferreira (CERN) et al.
- TUP049, F. Furuta (Cornell) et al.
- TUP052, Y.I. Ida (MGH) et al.
- TUP053, A.A. Sulimov (DESY) et al.
- TUP054, E.J. Taylor (Faraday Technology, Inc.) et al.
- TUP055, Y. Yang (ANL) et al.
- TUP056, A. Matheisen (DESY) et al.