

# **Observations of Spontaneous Field Emission Occurrence with Subsequent Cavity Performance Degradation – or,**

## **“What Just Happened?”**

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# Introduction

Field emission (FE) has been with us since the beginning. Great strides have been made in eliminating or reducing it. Yet, it still occurs.

## **“Normal” FE Behavior (a “bad” cavity)**

- Onset at some moderate field level
- Increases with increasing field
- Can lead to quench
- Can lead to low Q (Q-drop, FE loading)
- Increased radiation/dark current affects operation in CM

## **“Anomalous” FE behavior (a “good” cavity gone “bad”)**

- Onset typically at higher fields
- Sharp increase in radiation, to very high level
- Radiation remains active below original onset, in previously FE-free zones
- Q is decreased compared to non-FE performance
- Maximum field is lower



## Examples from 9-cell tests

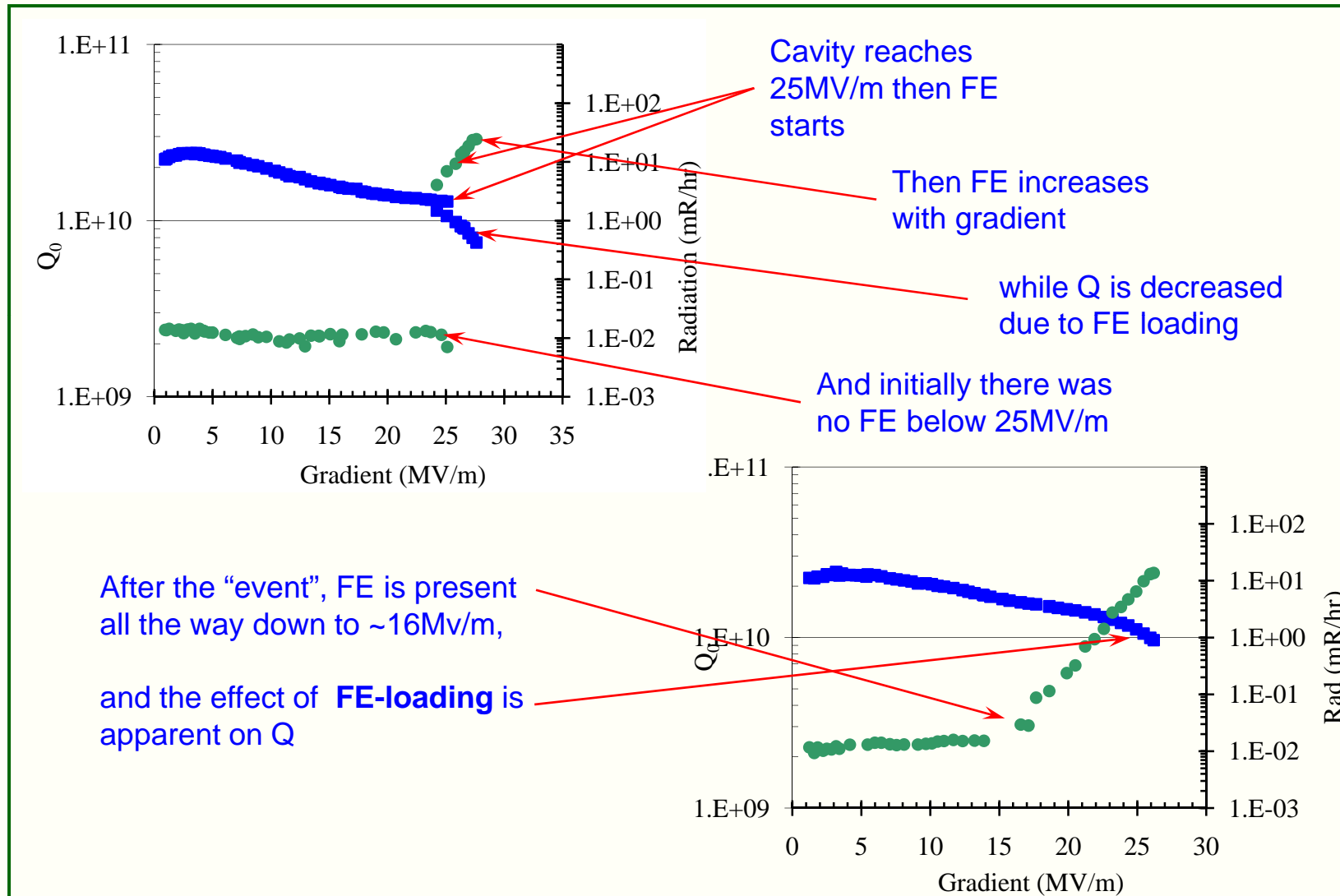
There have been 5 instances of this phenomenon observed during 9-cell cavity tests at Fermilab over the past ~20 months (55 tests). It is rare – 9% of the time.

- TB9ACC014 tested 5/1/2009
- TB9ACC006 tested 5/11/2009
- TB9ACC007 tested 11/6/2009
- TB9RI026 tested 4/26/2010
- TB9ACC015 tested 2/18/2011

Four of these cavities were subsequently re-processed and re-tested. TB9RI026 was re-processed and is in the test preparation queue, while TB9ACC015 is awaiting further activity.

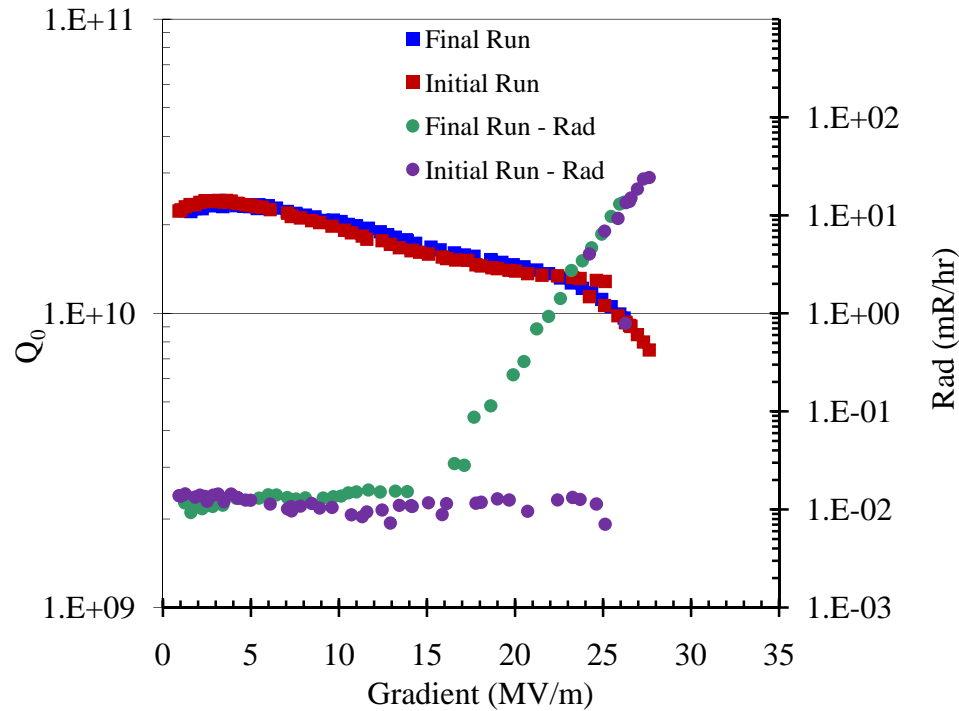


# TB9ACC014





# TB9ACC014

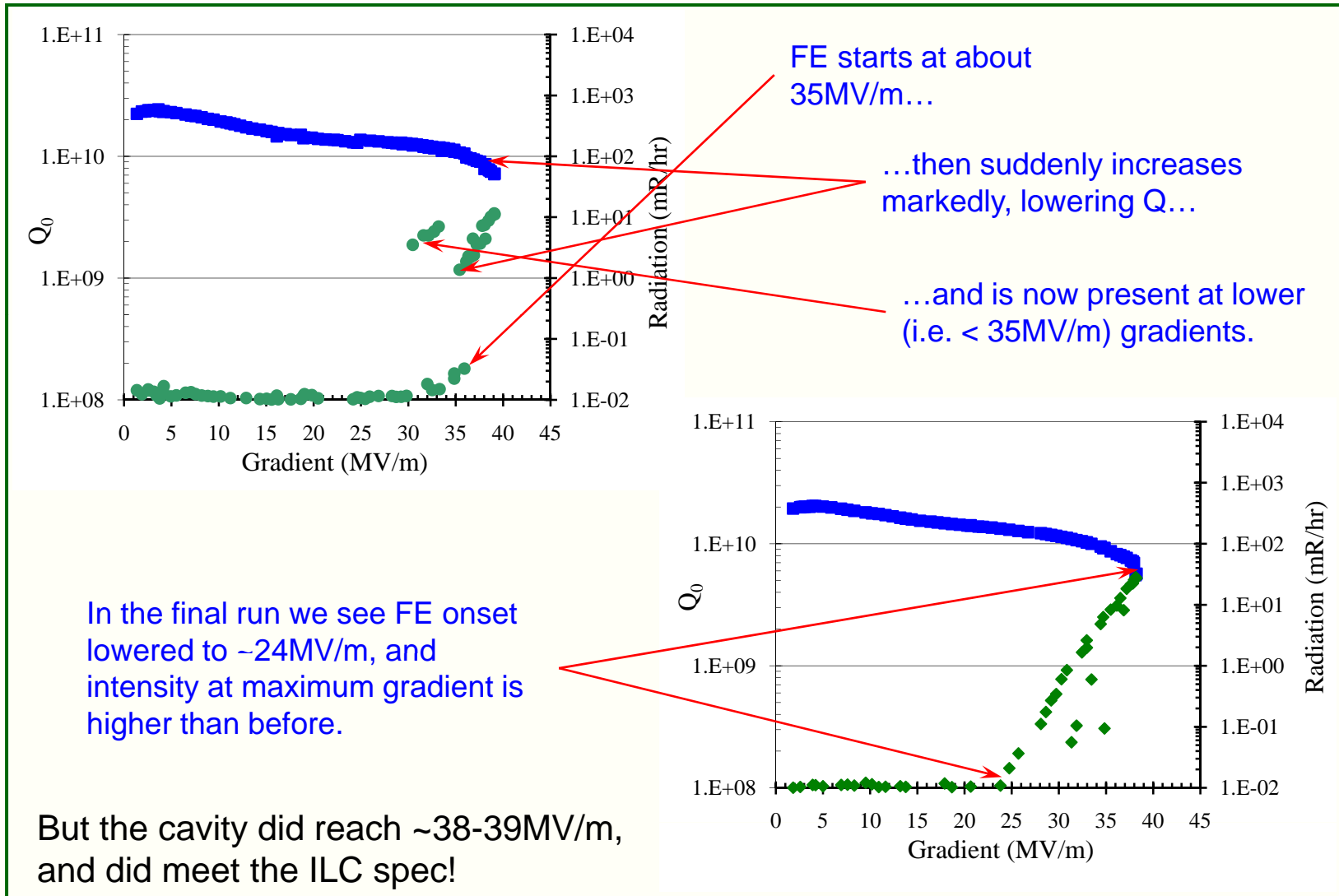


Before/After plot clearly shows performance degradation (effect on Q) and earlier FE onset.

Cavity received additional HPR and was re-tested ~2 weeks later.

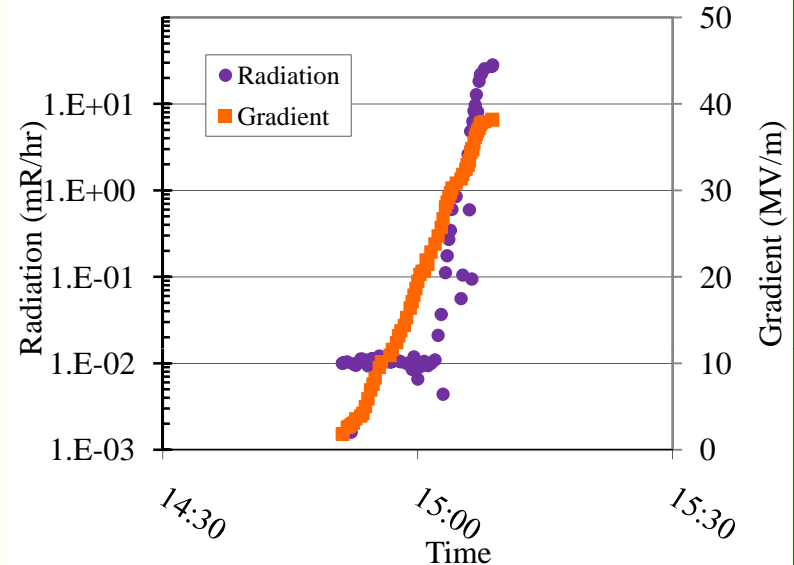
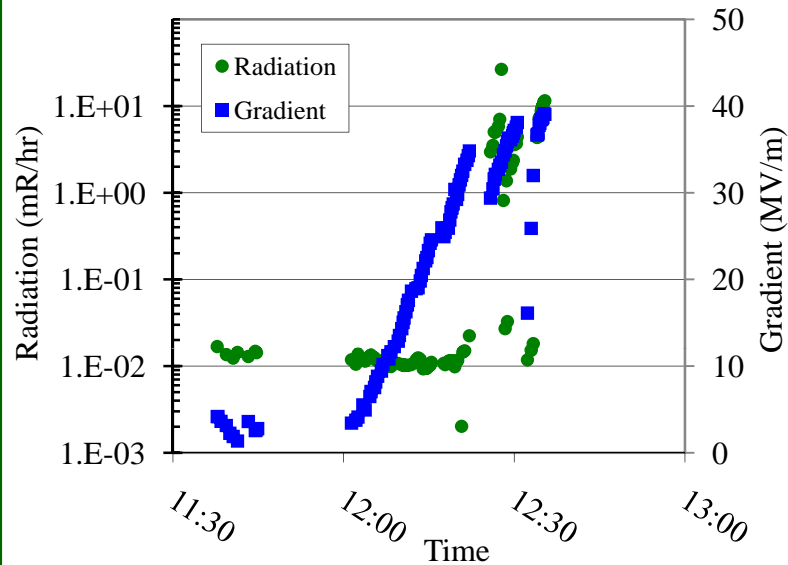


# TB9ACC014 – “Dejavu all over again”





## TB9ACC014 – “Dejavu all over again”



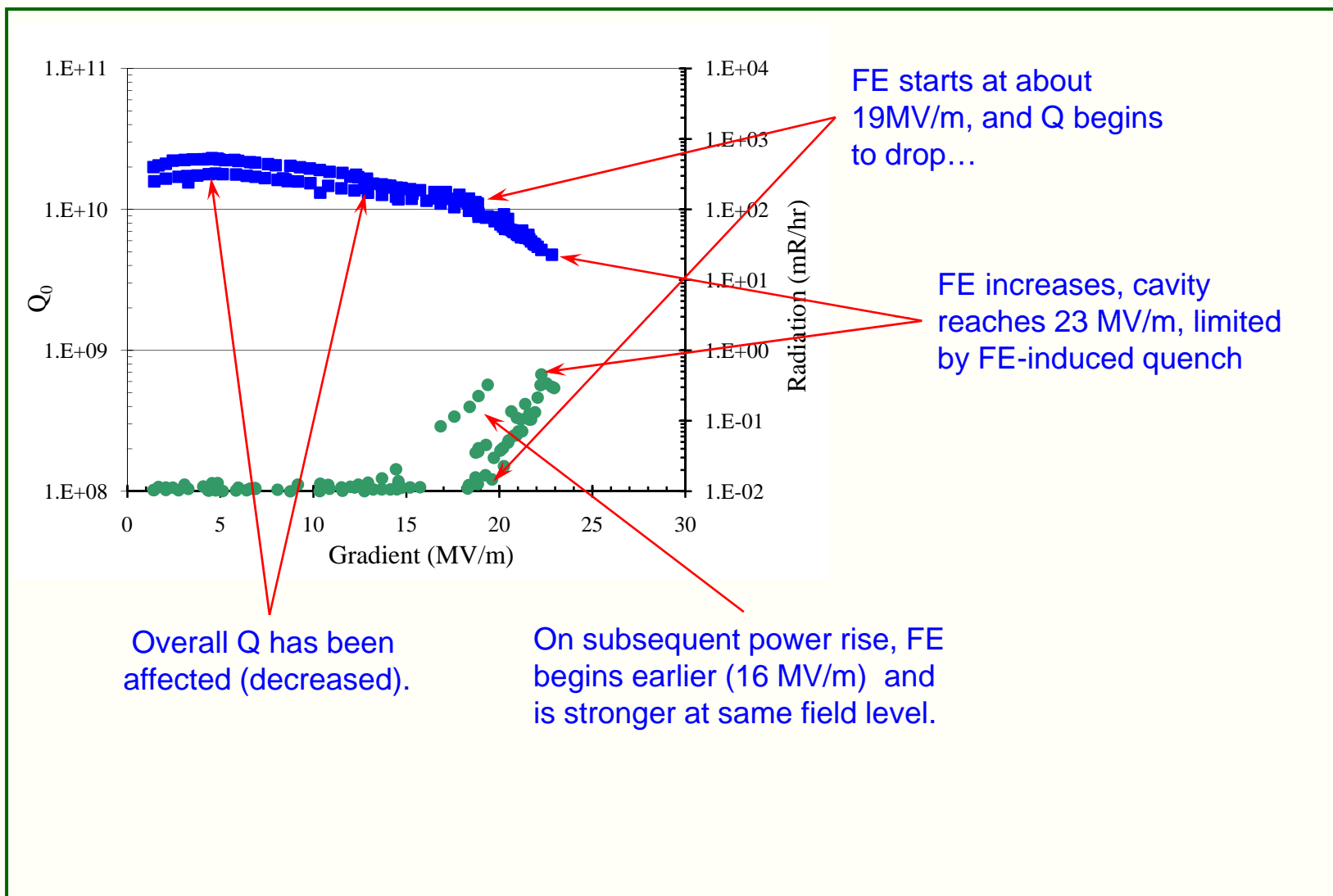
Plot of gradient/radiation vs time also clearly shows this change in FE behaviour.

Cavity was subsequently damaged (dent in cell #9), repaired (cell #9 de-tuned by ~20%), and re-tested. Quench limited (FE) to 30MV/m.

The cavity was then given additional HPR and re-tested... quench limited to 34MV/m, with some FE. No more “events”.



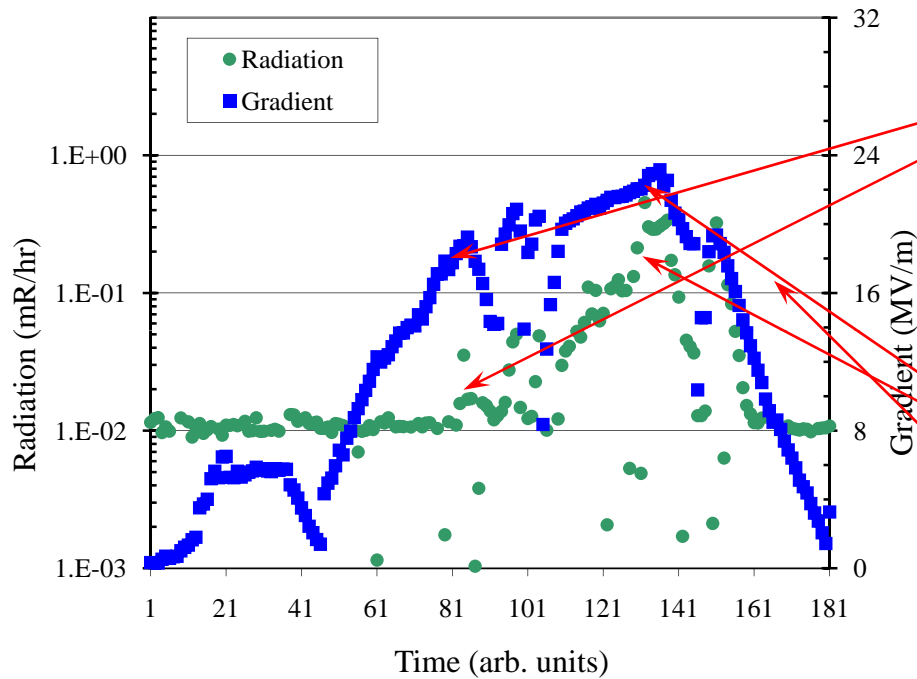
# TB9ACC006







# TB9ACC006



FE starts at about 19MV/m, and Q begins to drop...

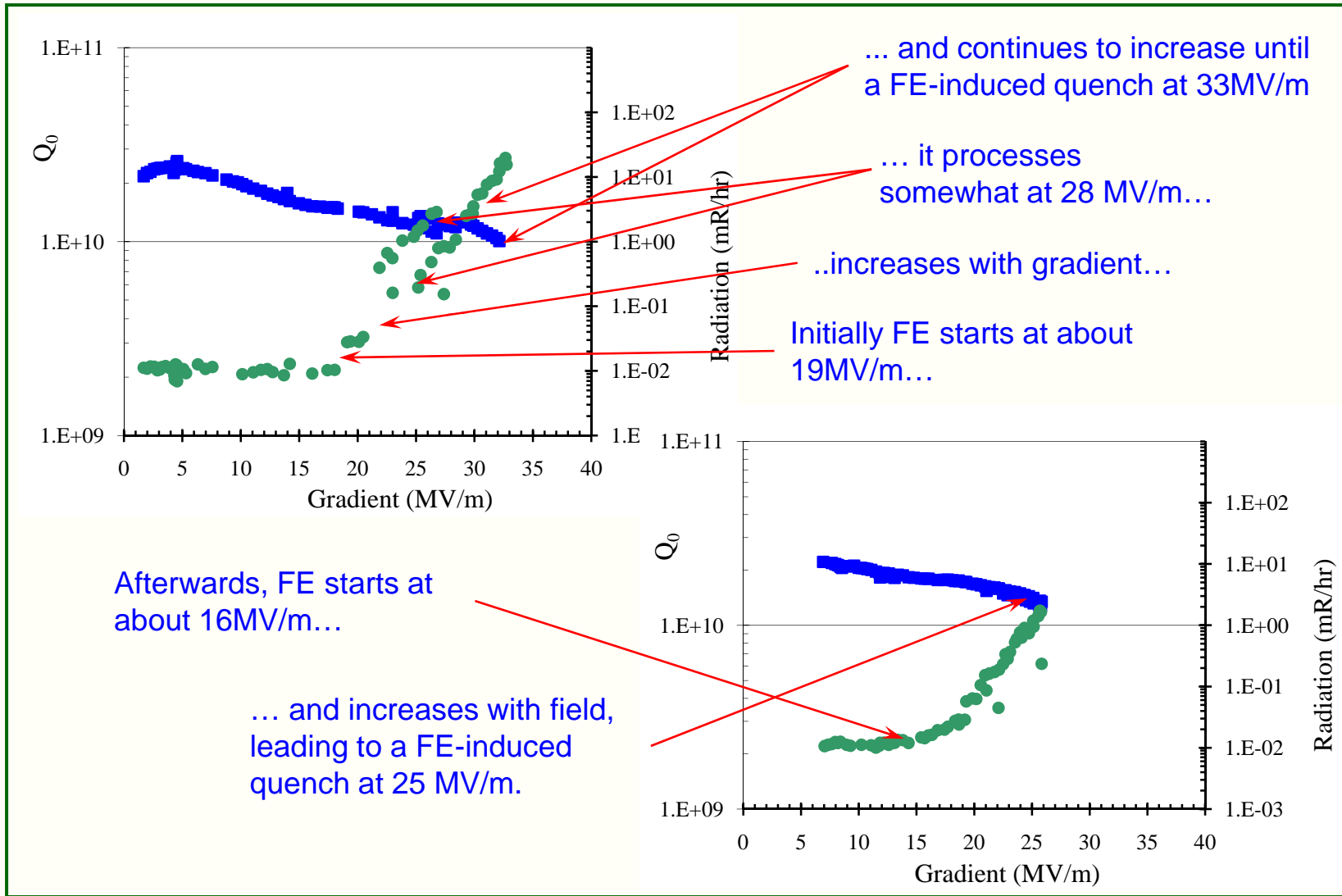
FE increases, cavity reaches 23 MV/m, limited by FE-induced quench

On subsequent power rise, FE begins earlier (<16 MV/m) and is stronger at same field level.

Cavity was reprocessed (light EP, HPR) and then sent to JLab for vertical test, then returned to FNAL for vertical test. Cavity reached 32 MV/m (quench, w/some FE present) at both labs.



# TB9ACC007





## TB9ACC007

Cavity received additional HPR, then re-tested, reaching 26 MV/m. FE onset was at 23 MV/m, but radiation quite low. Quench traced to cell #8.

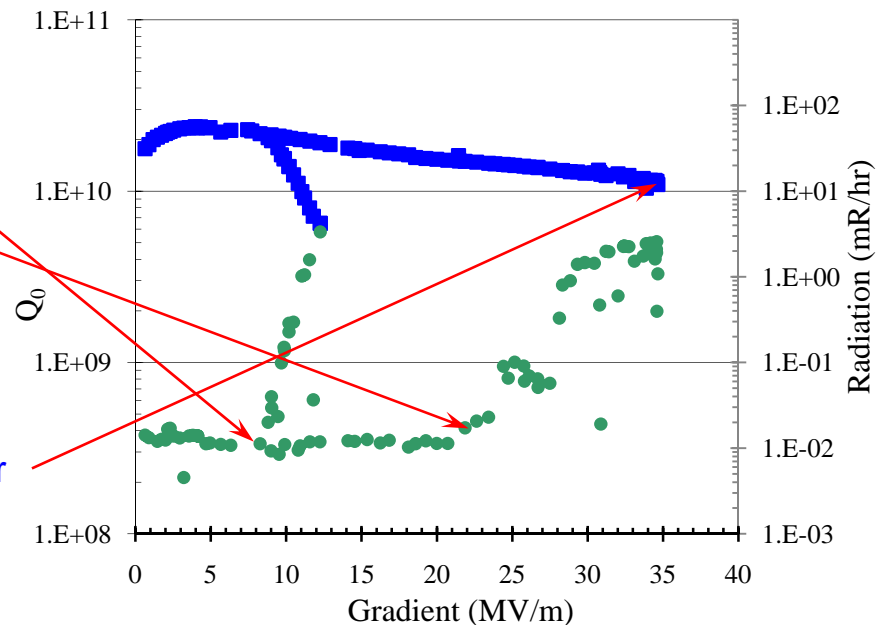
Suspect that “explosive” FE observed during first test may have deposited a particle on the surface that was not removed by HPR alone.

Next step – light EP, then HPR, etc. and re-test.

Early FE onset (< 10 MV/m),  
but processed away...

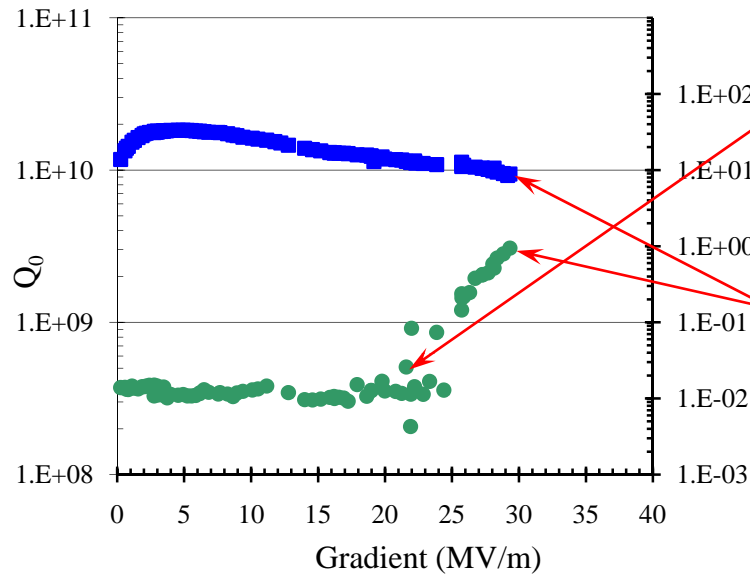
... FE returns at ~22MV/m  
and increases...

... but cavity now reaches 35 MV/m,  
limited by quench in either cells 1, 4, 6, or  
9. Cell #8 is no longer the limiting cell.





# TB9RI026

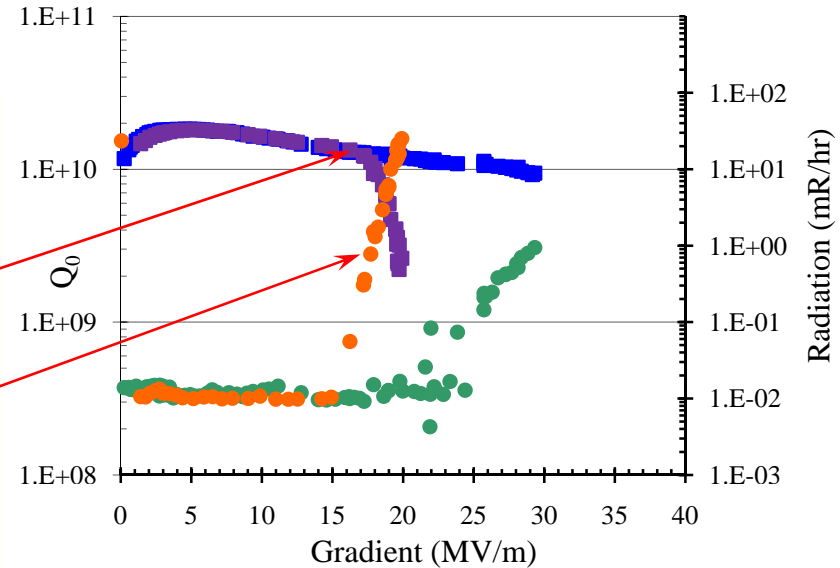


FE initially begins ~22-23 MV/m, leading to a few FE-induced quenches, some spontaneous processing is observed...

... FE becomes stronger once cavity reaches ~ 25 MV/m, and continues to increase... but Q remains good, and cavity reaches 29 MV/m...

... but once cavity reaches 29 MV/m it quenches, (from FE presumably) and does not recover.

On the final run a drastic Q-drop is observed at ~16MV/m, accompanied by very high radiation, which now starts at ~ 15MV/m. Cavity is limited to 19.6 MV/m





## TB9RI026

(Optical inspection results by D. Sergatskov)

Optical inspections of TB9RI026 revealed a huge “crater” on the iris between cells 8/9, which got larger as EP was carried out.



After 1<sup>st</sup> EP

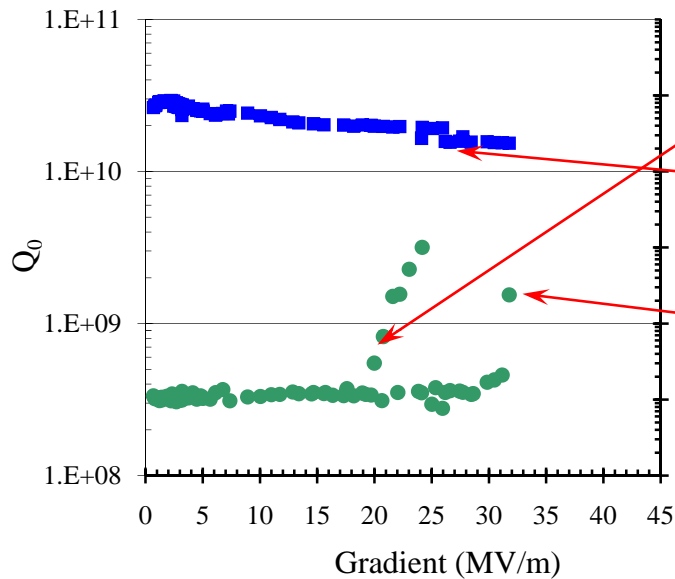
After 2<sup>nd</sup> EP  
Diameter ~ 350-400  $\mu\text{m}$



Cavity was sent to KEK for repair by local grinding, then light EP, HPR. Will be prepared for vertical test at FNAL next.



# TB9ACC015



FE initially begins at 20 MV/m, but spontaneously processes away by 23 MV/m

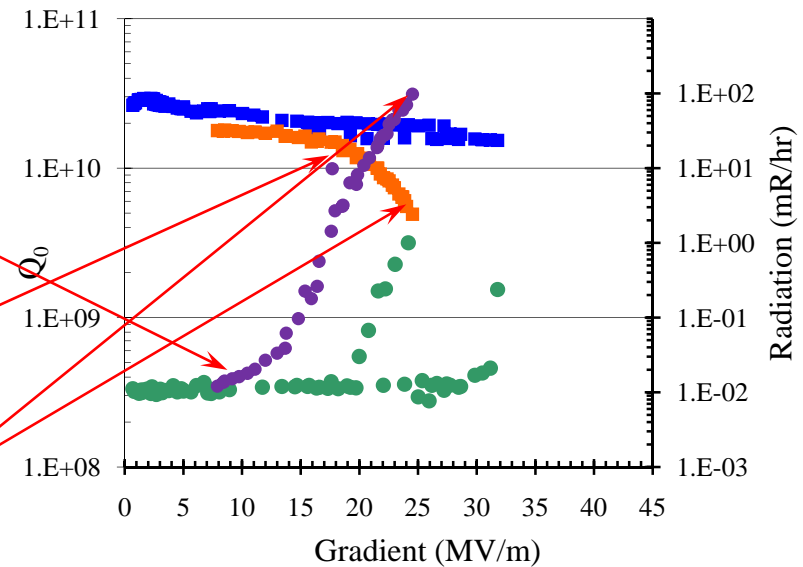
After the FE processes away, the Q is slightly lower

And then FE appears again at 32 MV/m, increasing rapidly and quenching the cavity

After the "event", FE now begins much earlier - 8-9 MV/m...

...and leads to strong FE-loading of the cavity - Q-drop begins at 16MV/m...

...and the cavity is essentially limited to 25MV/m, with very high radiation





## TB9ACC015

Next steps for TB9ACC015... optical inspection, then additional tumbling/EP...



## Summary

Cavity	$E_{FE}$ Onset before event	$E$ @ event	$E_{FE}$ Onset after event	$E_{max}$ after event	Next process	$E_{FE}$ Onset latest	$E_{max}$ latest
TB9ACC9014	25	25	16	28	HPR	35	38
TB9ACC9014 (part deux)	35	36	24	38	Tune, HPR	25	34
TB9ACC006	19	19	16	23	EP & HPR	29	32
TB9ACC007	19	33	16	25	HPR, EP & HPR	22	35
TB9RI026	22	29	15	20	Grind & EP	-- --	-- --
TB9ACC015	20	32	9	25	Tumble & EP	-- --	-- --





## Summary

- **In a handful of tests, FE “events” are observed that subsequently degrade cavity performance**
  - It occurs without warning
  - It is not always accompanied by earlier FE
- **It is suspected that “violent” emitters can “pollute” a cavity by spreading debris onto the surface of the cavity. If this debris lands on high field regions**
  - FE onset may decrease
  - radiation may increase markedly
  - strong Q-drop or FE-induced quenches can occur
- **Cavity performance can usually be recovered by additional processing steps**
- **Only (partial) avoidance technique is to not exceed “acceptance spec” when testing production cavities.**