SNS Cryomodule Production At Jefferson Lab

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Outline

- JLab Production Requirements
- Difficulties in Qualifying Cavities
- Process Review and Findings
  - Procedures and Process Facilities
- New Process Sequence
- Current Performance
- Remaining Tasks For High Beta Cavities
- Conclusion

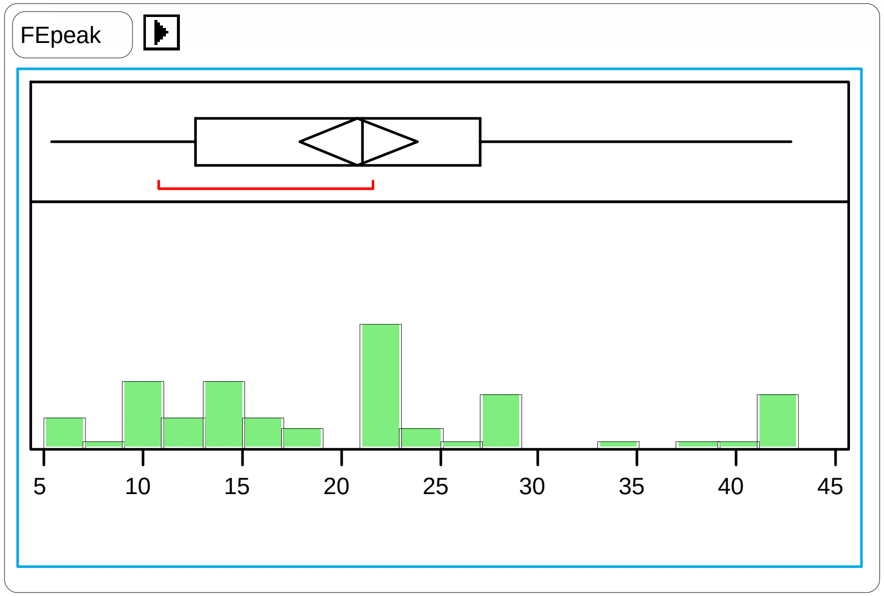
JLab Production Requirements

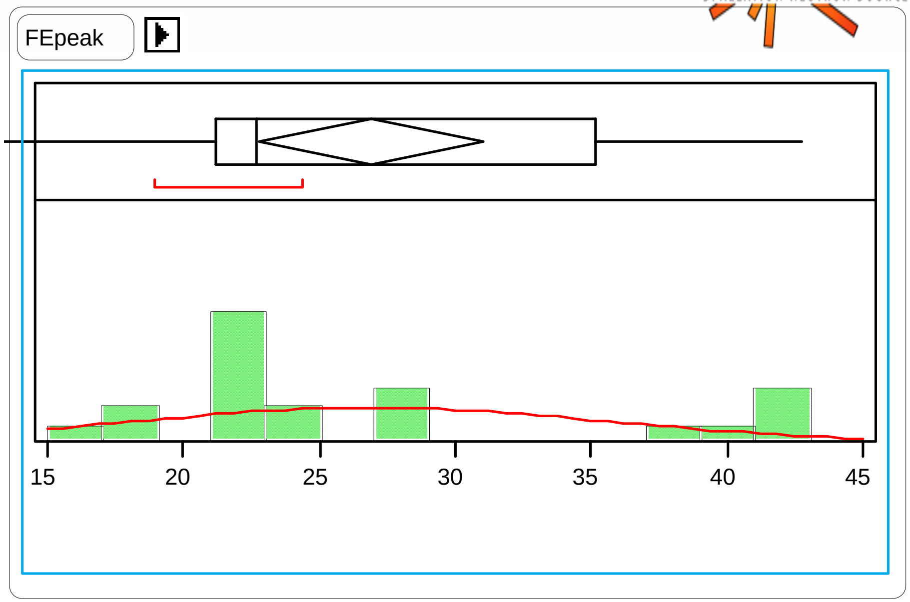
- Medium Beta Cryomodules
  - Produce 11 strings of 3 cavities each
  - **Couplers**
    - 50 ohm
    - 50KW average power
    - Peak Power 550KW @ 1.3 ms 60Hz
  - **Cavities**
    - Beta = 0.61, 805 MHz
    - Epk/Eacc = 2.71, Bp/Eacc = 5.72 mT/(MV/m)
    - R/Q = 279 ohms
    - VTA Qualifying Gradient - Eacc >10 MV/m @ Q- 5E9, 2.1K

JLab Production Requirements

- High Beta Cryomodules
  - Produce 12 strings of 4 cavities each
  - Cavities
    - Beta = 0.81, 805 MHz
    - Epk/Eacc = 2.19 Bp/Eacc = 4.72 mT/(MV/m)
    - R/Q = 483 ohms
    - VTA Qualifying Gradient - Eacc >16 MV/m @ Q- 5E9, 2.1K

–MB VTA Cavity Performance - Epk @ FE onset (MV/m)





All Vertical Tests

N – 51

Mean – 20.94

Std Dev – 10.46

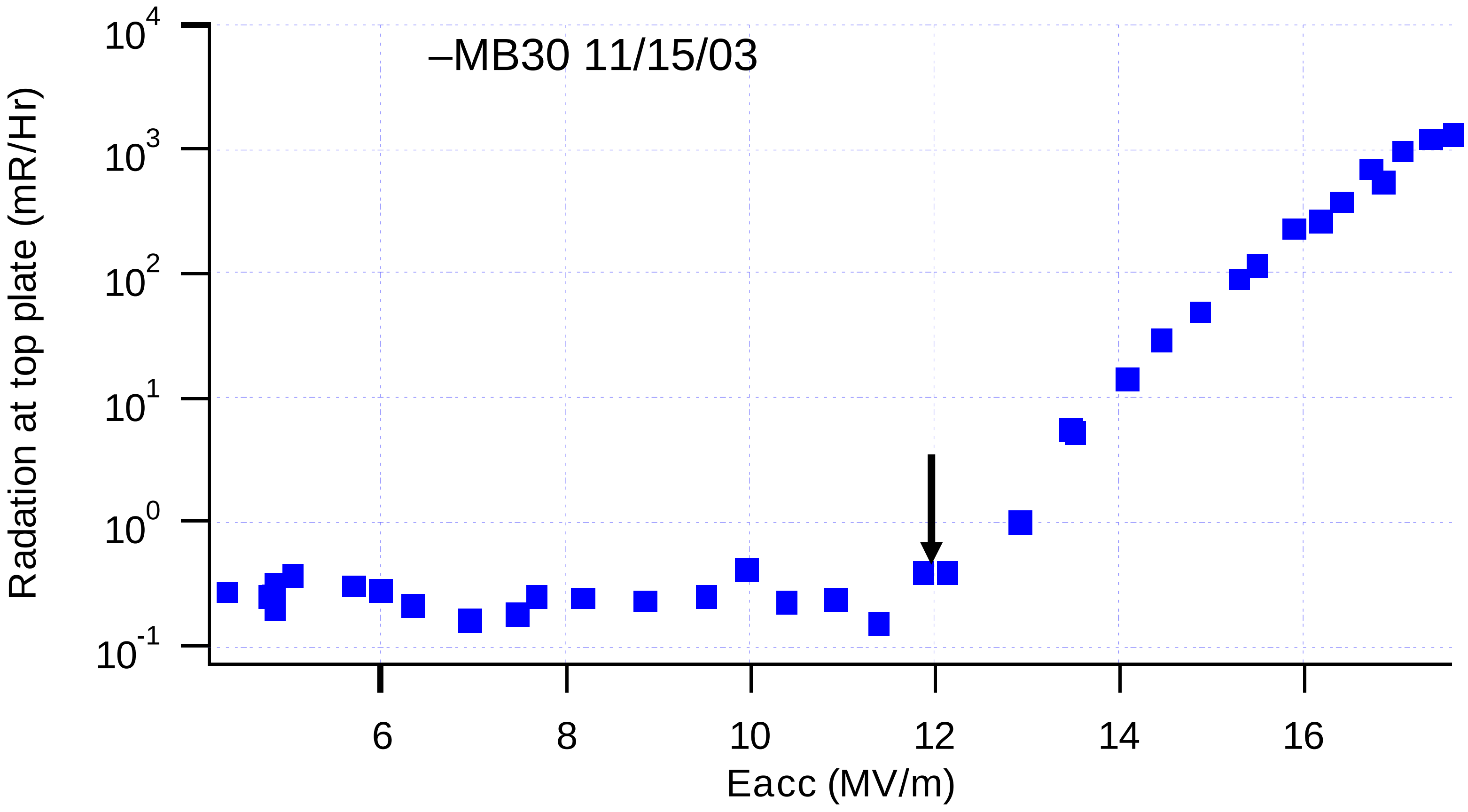
Qualified for String Assembly

N – 21

Mean – 26.94

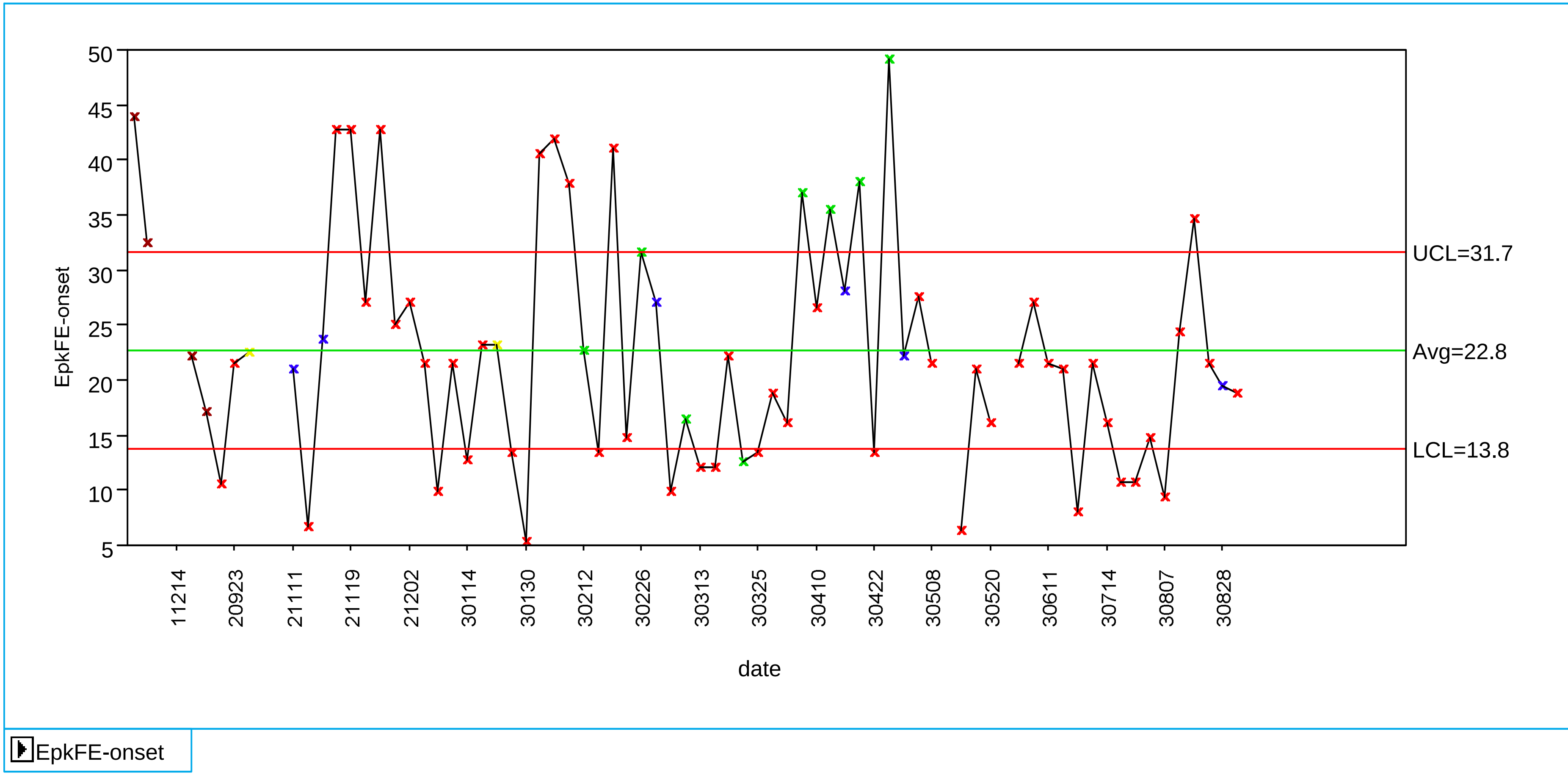
Std Dev – 8.74

Definition of Field Emission Onset - JLab

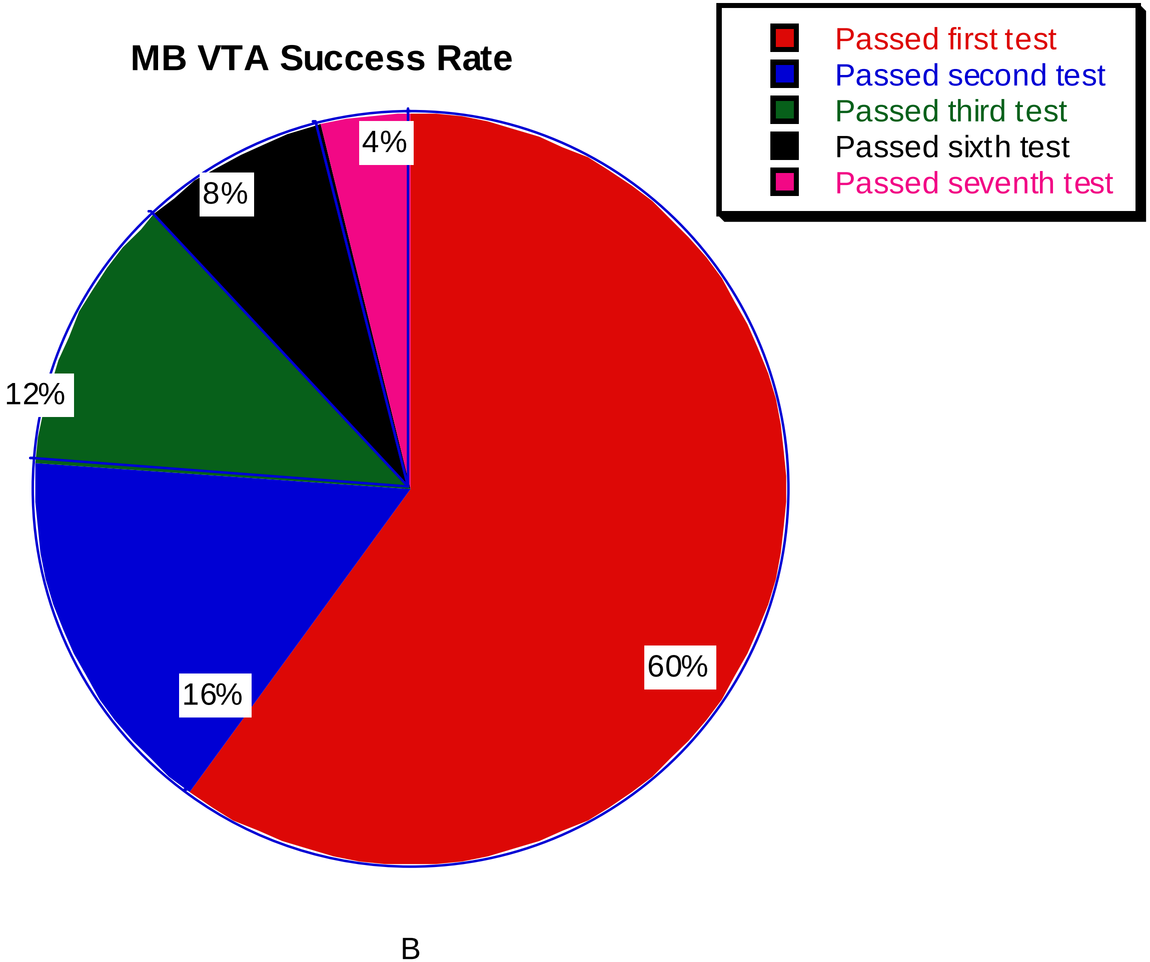


Field Emission Onset Chronologically

VTA Test Data All Cavities



Difficulties in Qualifying Cavities



Process Review and Findings

- JLab held an internal review September 15th 2003
- October 15th 2003 SNS held an external review of cryomodule production at JLab
  - External review team consisted of the following:
    - Helen Edwards, FNAL – Chair
    - Peter Kneisel, Jlab
    - Hassan Padamsee, Cornell University
    - Yanglai Cho, ANL
    - Carlo Pagani, DESY-TESLA/ INFN
    - Axel Matheisen, DESY
    - Lutz Lilje, DESY
    - Detlef Reschke, DESY

Process Review and Findings

- Additionally:
  - Norbert Holtkamp and Carl Strawbridge, SNS
  - JLab Management and staff

- The focus of the review was to identify possible improvements to procedures to increase cavity qualification rates

- Special attention to existing procedures, facilities and comparison to DESY TESLA procedures identified many areas of possible improvement.

- A general review of what was known about pushing out field emission was also very constructive.

Production Sequence- Receiving Inspection

	Receiving Inspection
1	Cavities moved into testlab receiving area
2	Initial inspection of cavities
3	Cavity is moved into QA lab
4	Mechanical inspection
5	Cavity is moved up to RF tuning area
6	RF Inspection

– Find more info on Accel's process

– No internal inspection performed

Production Sequence- Heat Treatment

	Heattreatment
7	Cavity is moved to chemroom
8	Cavity is Degreased in US
9	Cavity is moved to RF tuning area
10	Insertion into the furnace
11	Furnace run

- Rinse to Resistivity and etch before HT
- Drying after degreasing
- Should change to a liquid detergent vs powder

Has not been implemented because all MB cavities were already heattreated ,

will happen on the HB cavities.

We are prepared for the change

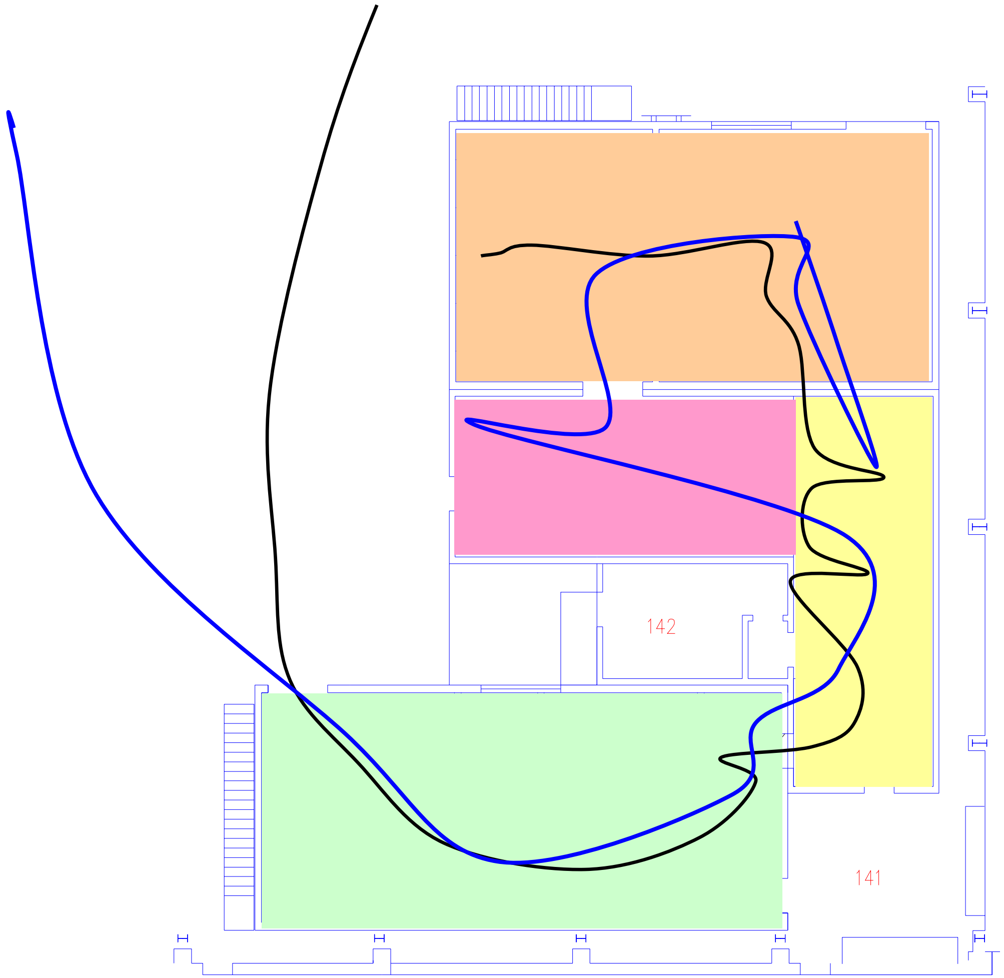
Production Sequence- Helium Vessel Welding

	Helium Vessel Welding
12	RF tuning
13	Cavity is moved towelding area
14	Component setup and alignment
15	Tack welding completed
16	All Welds are completed
17	Field flatness measurement
18	Cavity is moved to cryomodule assembly area
19	Leak Test of vessel

- Remove plastic caps and use metal seals
- Determine frequency by passband modes, seal cavity when possible

Again all MB and some HB were already welded so this will be implemented on the HB

Cleanroom Facility



Final Assembly

Final String Assembly

Cleanroom Chemistry

Pre-cleaning of Parts

Production Sequence- Vertical Test Qualification

	Vertical Test Qualification
20	moved into chemroom on transfer cart
21	Moved to passthru and cavity connected to lift straps
22	Inserted into Ultrsonic tank using overhead hoist
23	Ultrasonic 1 hour with DI and Alconox
24	Cavity removed from US tank
25	Cavity rinsed with DI water
26	Cavity placed back on transfer cart
27	Cart pushed into cleanroom passthru
28	Lift cart moved to cavity and connected and removed from transfer cart

Two step rinsing, ultrasonic degreasing + flowthru

Overflow ultrasonic + filtering

Move to cleanroom sealed

Improvements to degreasing were made – DI degreasing open then repeated with second DI no soap and improved rinsing, followed by drying in cleanroom ---next step is to install resistivity monitoring and flow thru

Production Sequence- Vertical Test Qualification

29	Cavity moved to open area and flange hardware installed
30	Cavity inserted into cabinet and acid connections made
31	Water leak test performed
32	Cavity Process Program Started
33	Acid mixed and filtered 15-30 minutes, nitrogen leak test
34	Acid flows thru cavity (20um)
35	Acid drains
36	DI Water rinse for 3 minutes
37	Three fill and dumps with DI water
38	Flange hardware removed
39	DI water rinse of flanges

More chemistry 100um

Waste acid after 10g/L

100um added and acid wasted after 15g/L , all string chem new acid

Increase fill/dumps & follow with a flowthru rinse to pH, transfer to HPR wet

Now 10 Fill & Dumps minimum (pH), flanges changes, flow thru to 5-6M ohm cm

Production Sequence- Vertical Test Qualification

40	Cavity moved to HPR cabinet
41	Cavity inserted into cabinet and aligned
42	HPR Program Started
43	Pump starts and wand and table move
44	Wand moves up and down and is repeated n loops
45	Cavity drains overnight
46	Cavity flanges blanked all but top
47	Lift cart attached to cavity
48	Cavity is removed from cabinet
49	cavity is transfer to short mast cart
50	Cavity is moved to Class 10 area
51	Cavity top flange assembled
52	Cavity probe flange assembled
53	Cavity HOM flange assembled

Total time 4 hrs, wand movement top to bottom, check effectively & duration

Cleanroom air top only, filtered nitrogen purge

Optimize nozzle size, position

Transfer to Class10 immediately after HPR & blank

Dry overnight

HPR time was increased X4

Nozzle optimization underway – fan jet best

Wet delivery to HPR

Immediate removal blank and dry over night

Production Sequence- Vertical Test Qualification

54	Cavity FPC flange assembled
55	Cavity HOM flange assembled
56	All hardware is torqued
57	Cavity is moved back to the main cleanroom
58	Cavity is transferred to the tall mast cart
59	Cavity inserted into HPR cabinet
60	Cavity HPR program started
61	Pump starts and wand and table move
62	Wand moves up and down and is repeated n loops
63	Cavity bottom flange blanked
64	Cavity removed from cabinet
65	Cavity is transfer to short mast cart
66	Cavity is moved into Class 10 area
67	Pumpout flange is assembled to cavity
68	Bolts are torqued

Nitrogen cleaning of hardware

Horizontal drying

2x HPR w/drain in between

Drain by flipping then dry overnight

Evacuate & isolate &move out of cleanroom, assembly to stand

Nitrogen cleaning of parts performed

No Horizontal drying attempted

No flipping but dry overnight

Evacuation and isolation in cleanroom

Production Sequence- Vertical Test Qualification

69	Cavity is moved into vertical attachment room
70	Cavity vacuum connection is made
71	Vacuum pump is started
72	Cavity is isolated and cold trap removed from rough pump line
73	Vacuum pump is started, pumps over night
74	Leak test of cavity and stand
75	Cavity moved into VTA parkinglot
76	Cavity vacuum is reestablished
77	Cavity HOM 's are tuned
78	Cavity is moved into dewar

Clean teststand

Cavity isolated from teststand?

Stop processing at sigh of FE

Surface resistance during pumpdown

Passband Q vsE

No HOM probes

High Power Connectors

Cavity isolated, stop at FEonset, some surface resistance at pumpdown

No HOM probes, standard cables

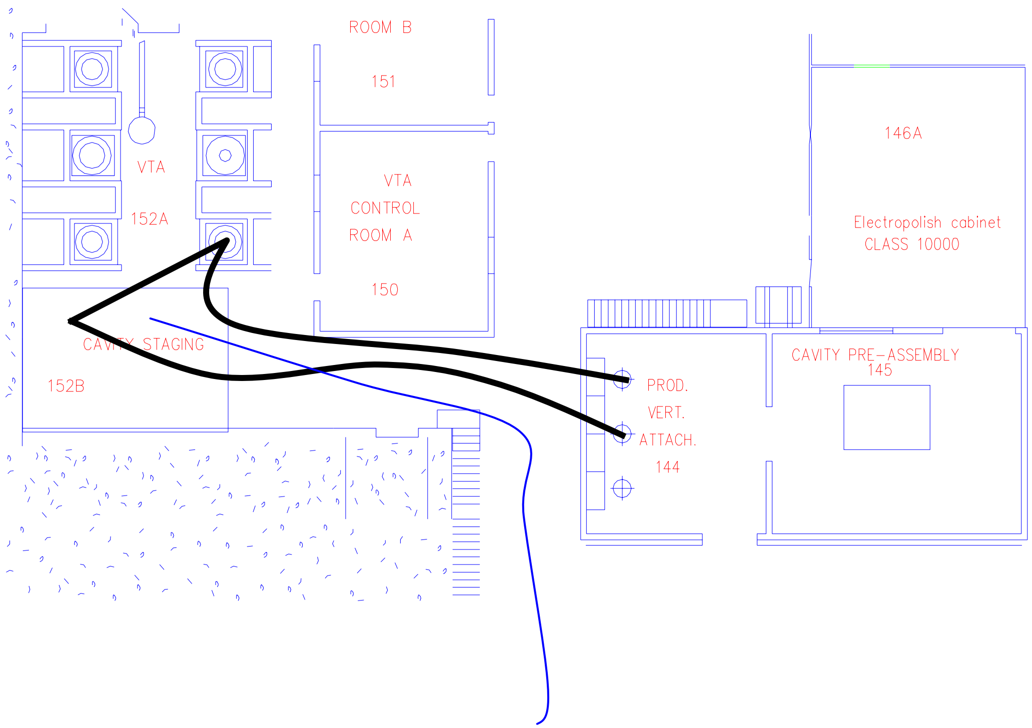
Production Sequence- Vertical Test Qualification

79	Dewar is qualifed
80	Dewar is cooled down and filled
81	Dewar is topped off and pumped
82	Cavity is RF tested
83	Dewar is warmed up
84	Cavity is moved back into cleanroom
85	Cavity is letup to nitrogen and disassembled

Backfill with N2 in a clean way

Backfill no longer on stand and in a clean way

Vertical Test Facilities



External Review Summary

- Review identified process changes that could improve performance
  - Additional rinsing after chemistry and for HP rinsing
    - JLab was HP rinsing a factor of two less for the surface area of these cavities
  - Keeping the cavity surface wet between chemistry and HPR steps
    - identified by DESY as important to reduce FE
  - Allowing the cavity surface to dry between HPR steps
    - dry surfaces are less likely to adhere particulates from subsequent procedures

External Review Results

- Adjust HPR head to increase the number of nozzles and reduce the nozzle diameter to increase impact force
  - Jlab's HPR works well on small diameter structures and was not optimized for these cavities
- Isolate cavities from test stand during RF testing
  - This reduces the possibility of cross contamination from the test stand
  - Back fill cavity after testing not through test stand
- Flow thru rinsing added during degreasing steps
  - Provides a more controlled way to ensure it clean
- Use fresh acid for final processing <10g/L Nb

Vertical qualification Sequence

– **Degrease - move to dry in Class 10**

– **Chemistry 100um , followed by 10 fills and dumps, rinse to 5 M ohm cm, wet transfer to HPR**

– **HPR 2 x 2 hours, 1200PSI drain in between, transfer to Class 10, dry overnigh**

– **Assembly probes & flanges**

– **HPR 2 x 2 hours, 1200 PSI, drain in between, transfer to Class 10, dry overnight**

– **Assembly of final flange, evacuate in Class 100, leaktest, isolate with valve**

– **Move out of cleanroom to vertical test area and insert into test stand**

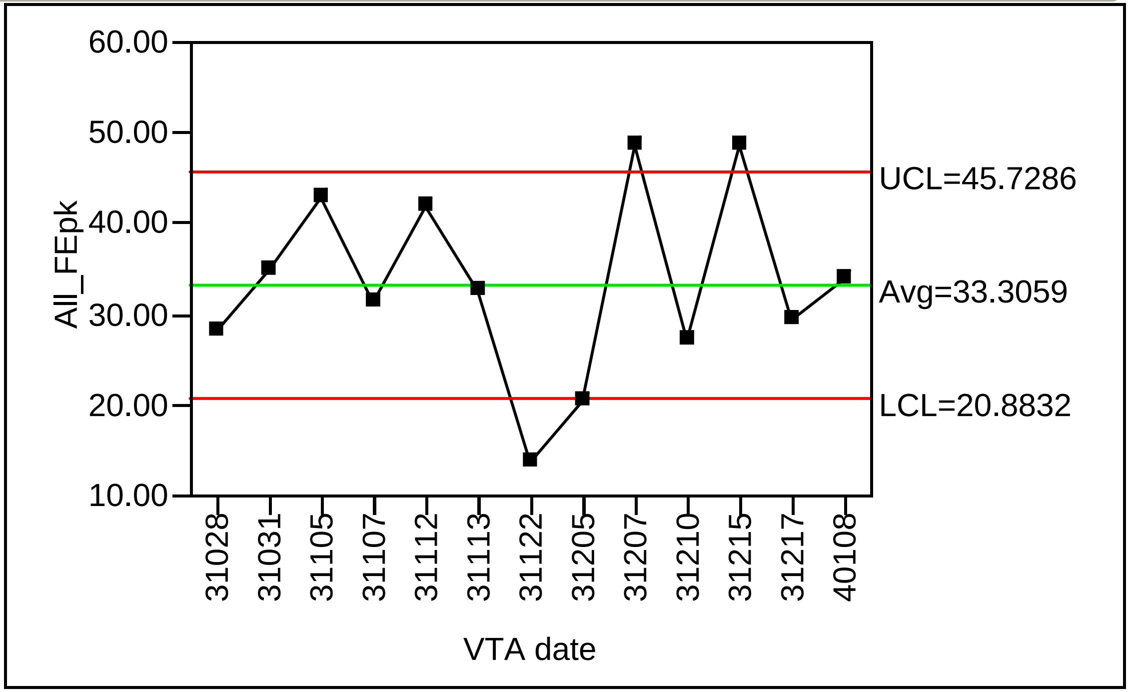
– **Insert into dewar and cooldown, fill and pump to 2.1K**

– **RF test, warm up**

Performance Immediately Improved

Control Chart

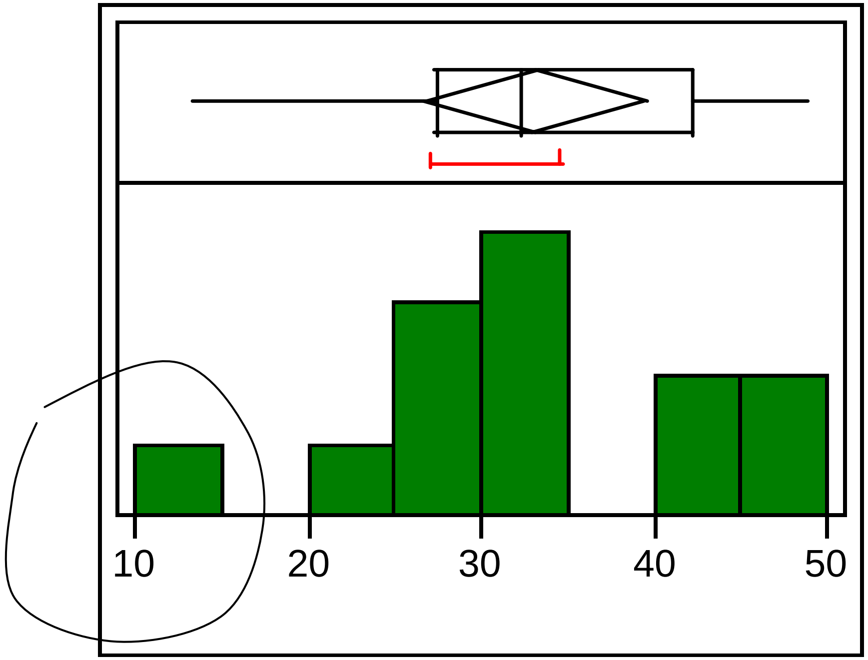
Individual Measurement of All_FEpk



Current Vertical Data

Distributions

All_FEpk

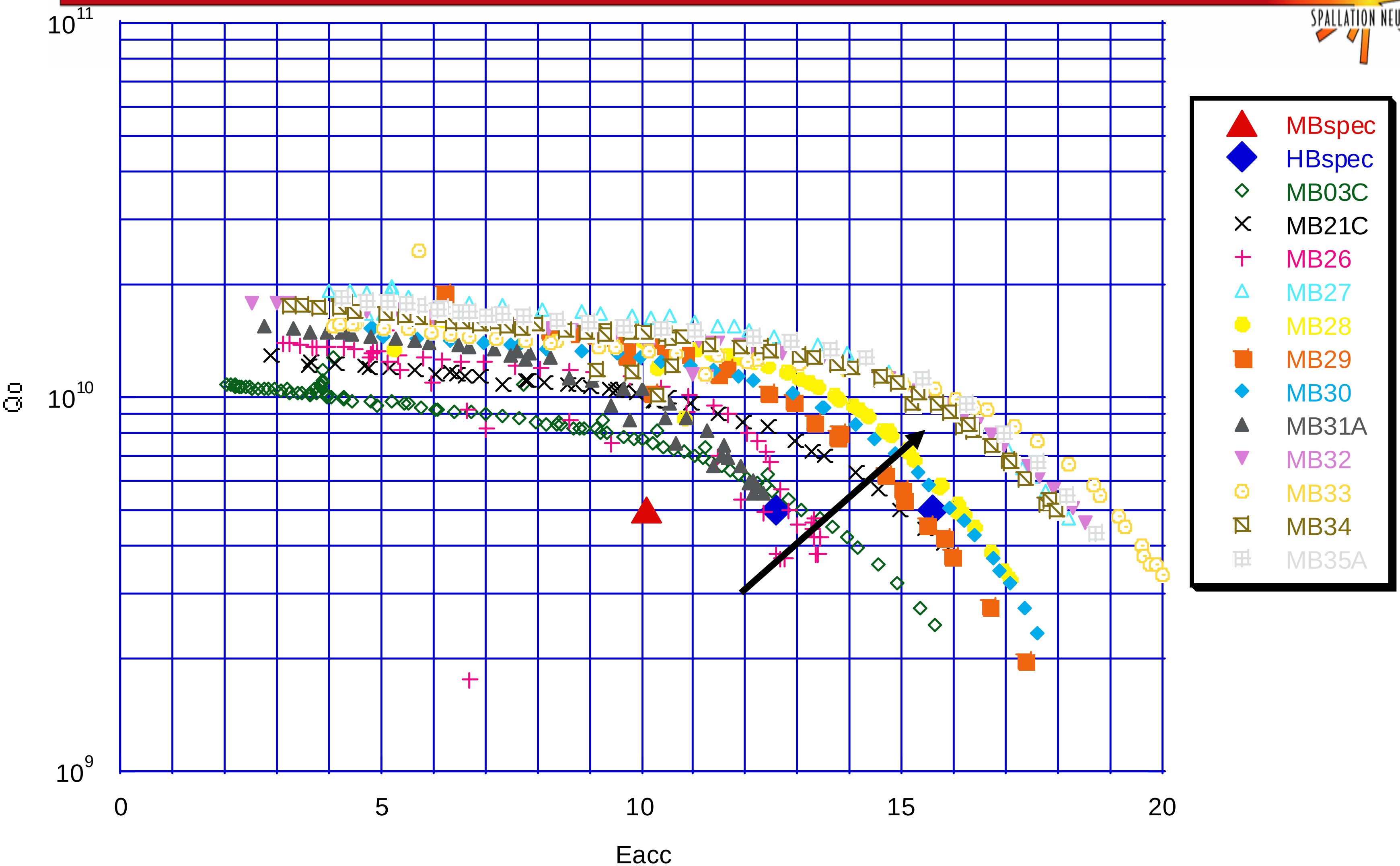


Moments

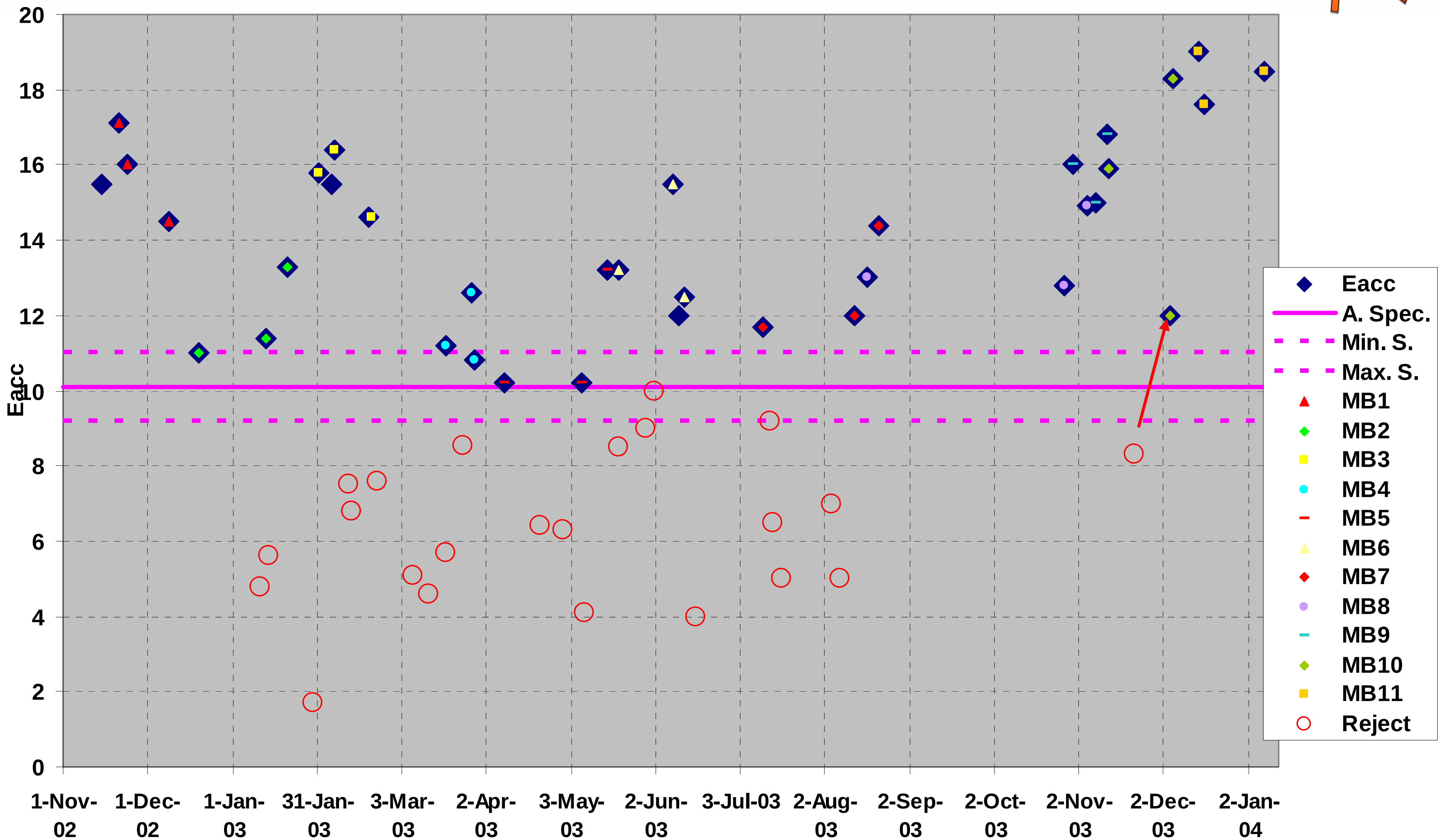
Mean	33.3059
Std Dev	10.37726
Std Err Mean	2.878134
upper 95% Mean	39.576815
lower 95% Mean	27.034985
N	13

–HPR Pump FAILURE

Vertical Data – new procedures



Vertical Test History



Remaining Tasks For High Beta

– **Add additional rinsing steps before furnace treatment**

– **Improve HPR reliability and effectiveness**

– **Develop EP procedures and demonstrate performance**

Conclusion:

- BEFORE THIS REVIEW:
  - Qualification rate was low due to early FE-onset
  - Epeak FE –onset – 21 MV/m, std dev 10.5
  - 50-60% success rate first test
- REVIEW IDENTIFIED AREAS OF IMPROVEMENT:
  - Process sequence modified dramatically
- CURRENT PERFORMANCE:
  - 12/14 passes first test
  - Epeak FE –onset – 33 MV/m, std dev 10.4
  - Two failures, both due to HPR pump failures
- More Improvements To Come