Status of The SNS SC Cavity and Cryomodule Production

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SNS Production At JLab

- **Production Requirements and Status**
  - **Fundamental Power Couplers**
  - **Cavities**
  - **Cryomodules**
- **Coupler and Cavity Performance**
  - **Vertical Test Results**
  - **Technical Issues Qualifying cavities**
- **Cryomodule Performance**
  - **Cryomodule Test Results**
  - **Technical Issues With Cryomodule Performance**
- **High Beta Cavity Electropolishing Status**

International Collaboration

SUBJECT	COLLABORATION
Cavity design	INFN Milan C.Pagani,P. Pierini,D.Barni,G.Ciovati
Mechanical Modes, Lorentz Force Detuning Mechanical Tuning	D. Schrage, LANL N. Ouchi, JAERI
Fundamental Power Coupler	KEK K.Saito,S.Noguchi,S.Mitsunobu
Higher Order Modes HOM Coupler	DESY J. Sekutowicz
Seal and Flange Design	DESY A. Matheisen
Multipacting (Cavity)	INFN Genoa R. Parodi
Multipacting (Cavity, Coax Coupler)	R.Nevanlinna Institute, Univ. of Helsinki P. Ylae-Oijala

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

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

Production Status

Couplers:

- 43 Medium Beta Couplers Qualified

Strings:

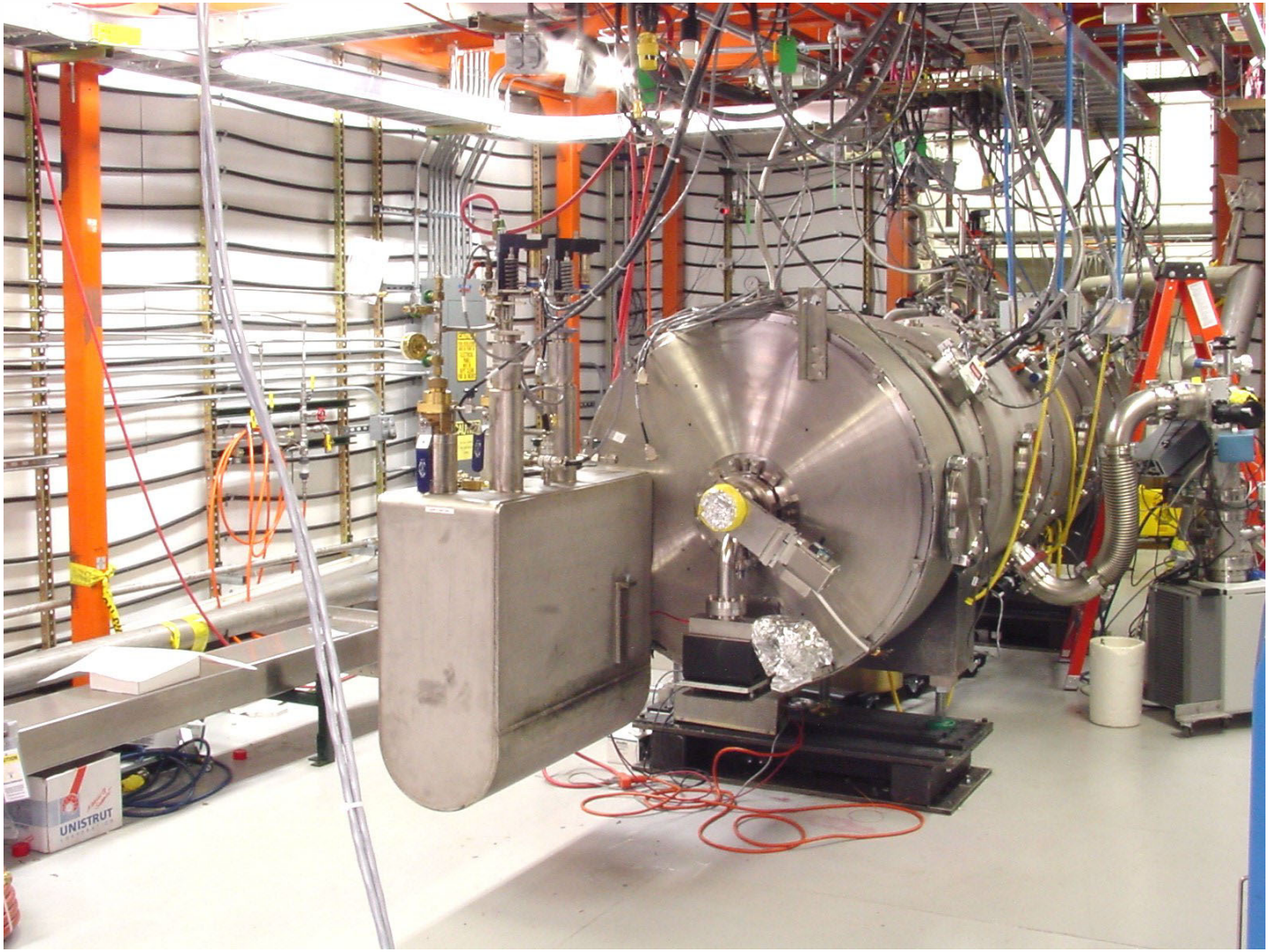
- 7 Medium Beta Strings Assembled ,M1-M7

Cryomodules:

- M1- M3 RF Qualified
- M4 – M6 Fabrication
- M7 Received

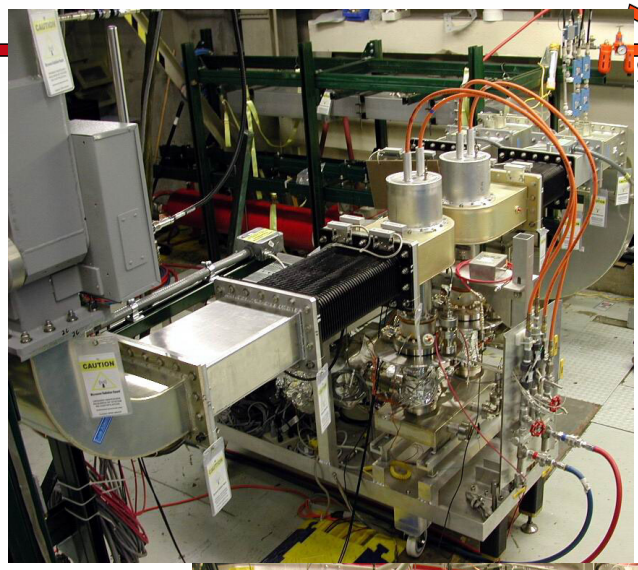
Cavity String Assembly

Cryomodule Testing

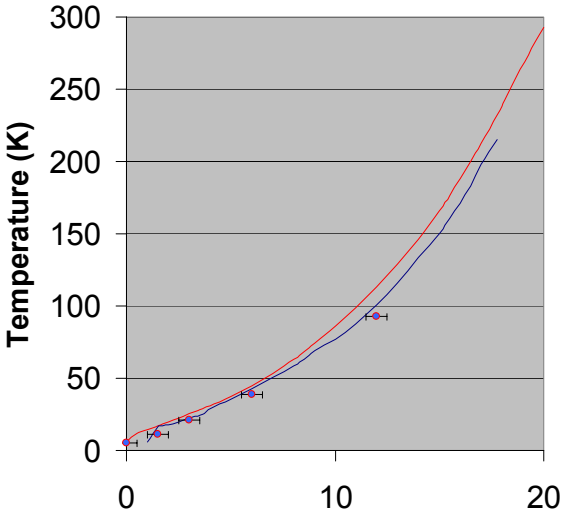


Fundamental Power Coupler Performance

- Pre-conditioning (baking 24 hours @ 200C 5 E-10 mbar)
- RF Conditioning and testing is done with 1MW TW,2.4 MW SW pulsed
- 43 of 44 FPC assemblies processed (4 assemblies took longer)
- Processing to 1 MW, typically 6-15 hours



Cryomodule Performance: Coupler



Power Coupler Outer Conductor Thermal Profile

Parameters:
Mass Flow = 0.030 g/s
Power = 100 kW CW
RRR = 10
Cu Thickness = 15 micron

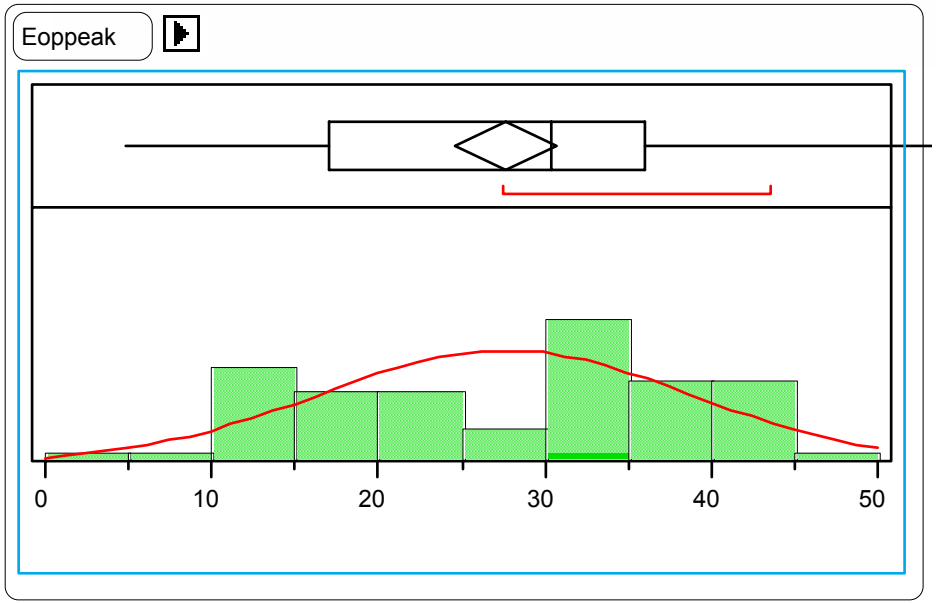
Heat Load/Temp. Estimate:
QHV = 1.1 W
Q293K = 25.8 W
Qloss = 6.7 W
Qexhaust = 31.4 W
He Gas Exit Temp = 215 K

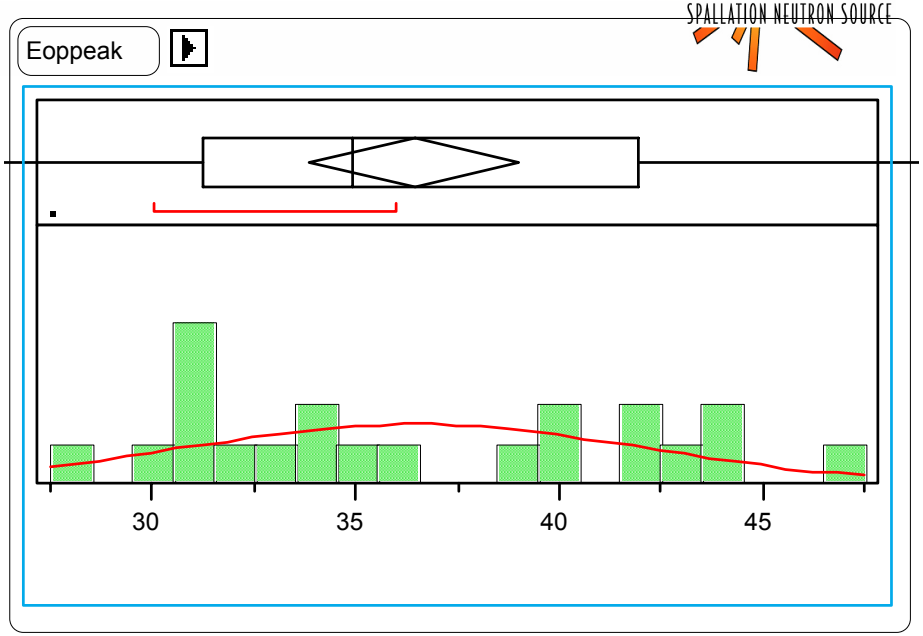
- Calculated Cu-Plated Inner Surface Temp (K)
- Calculated Helium Gas Temp (K)
- Sleeve Exterior Measured Temp. (K)

MB Assembly Sequence

- Initial inspection
- Mechanical inspection
- RF tuning
- Degreasing
- Furnace treatment 600C
- RF inspection
- Helium vessel welding
- Degreasing
- BCP 50um / HPR 2 hours
- Assembly / HPR 2 hours
- Assembly / evacuation /leaktest
- VTA RF test
- RF inspection / degreasing

MB VTA Cavity Performance – Epk @ Q=5E9 (MV/m)





All Vertical Tests

N – 51

Mean – 27.70

Std Dev – 11.12

Qualified Cavities Only

N – 21

Mean – 36.47

Std Dev – 5.64

Spec > 27.6 MV/m

Technical Issues Qualifying cavities

- Production Startup Seal Leaks

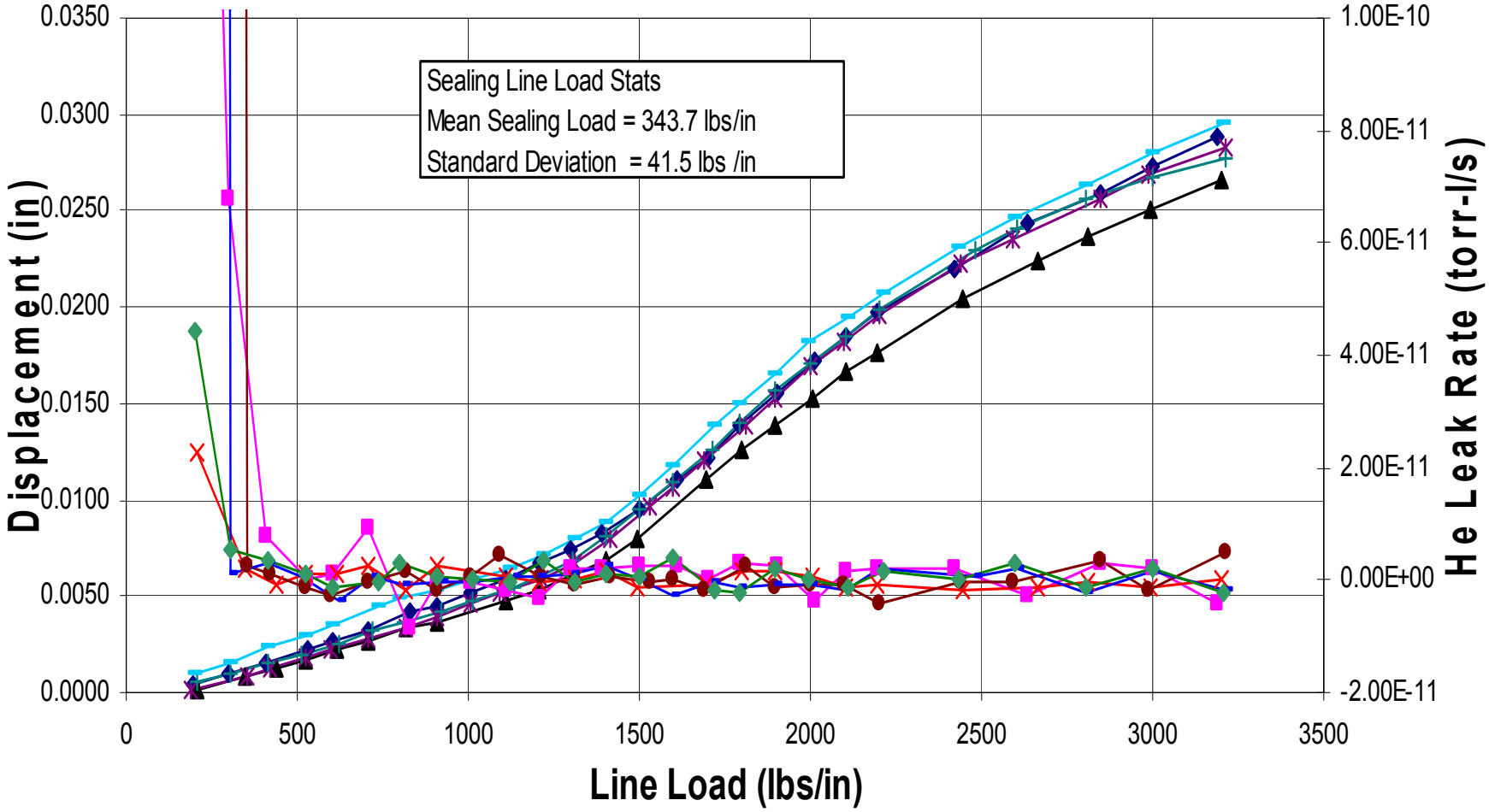
- Main Limiting Factor Early Field Emission Onset
  - This problem has led to many cable and connector failures during testing
  - Extended processing times has led to HOM probe breakdowns

Seal Leaks –Cavity Assembly

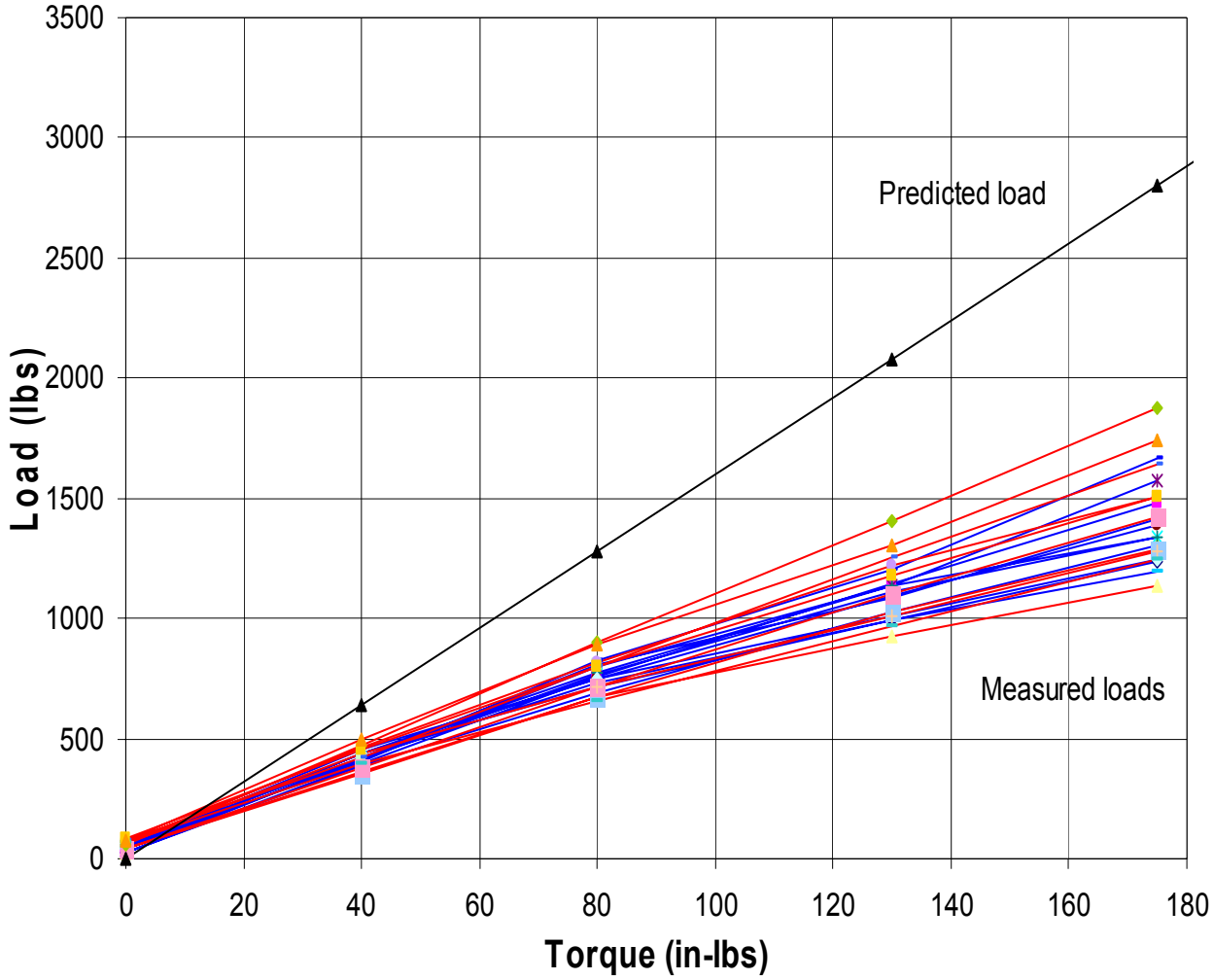
- Many leaks occurred during production startup, these leaks were attributed to:
  - Low seal line loading
  - Improper tolerance of mating components
  - Seal surface preparation (scratches)

- Issues were resolved with:
  - Higher torque values (40 ft-lbs) and higher strength bolts (A286)
  - Removing deep scratches
  - Better alignment of components during mating

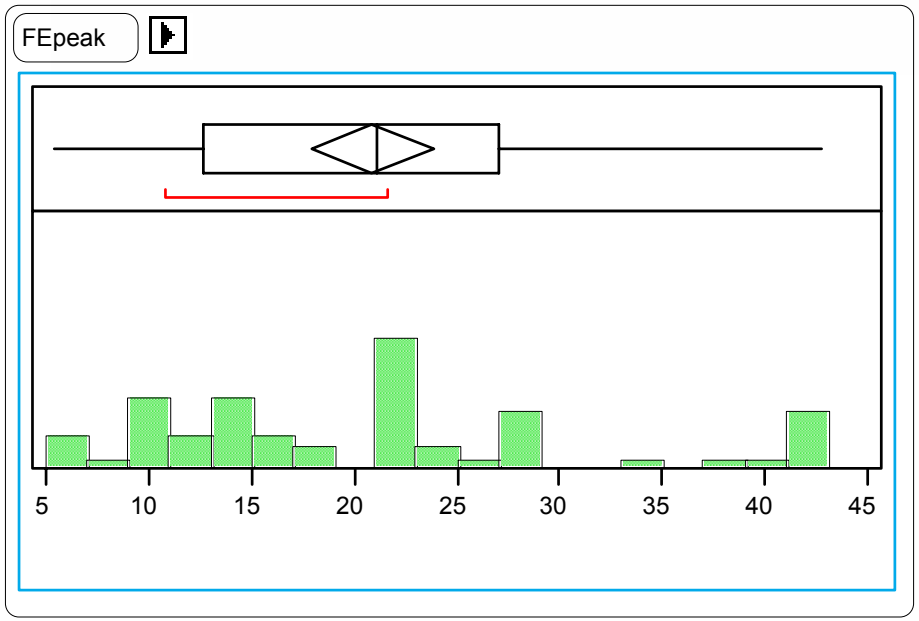
Seal Crush and Leak Rate vs Line Loading

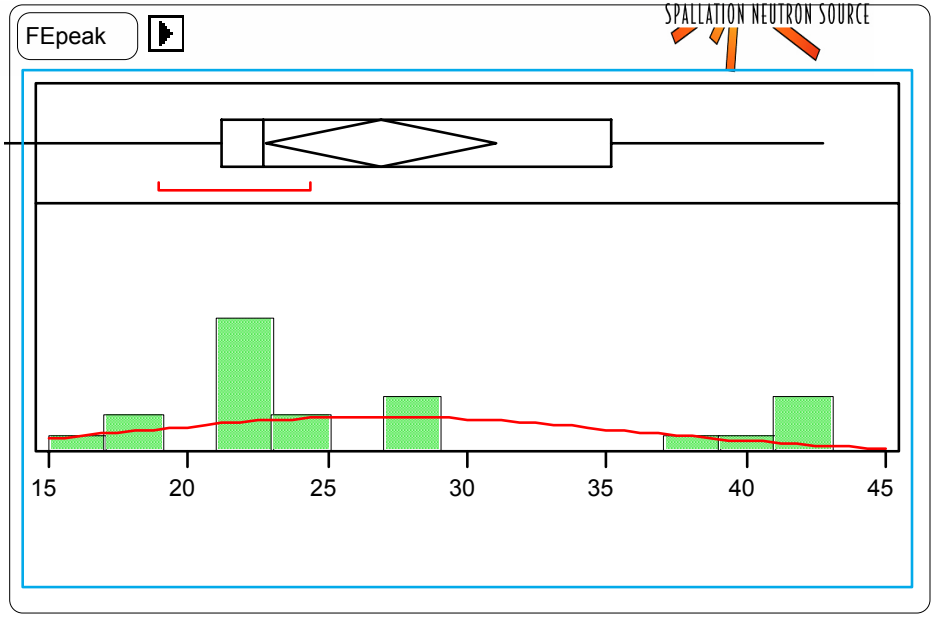


Bolt Loading vs Torque



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

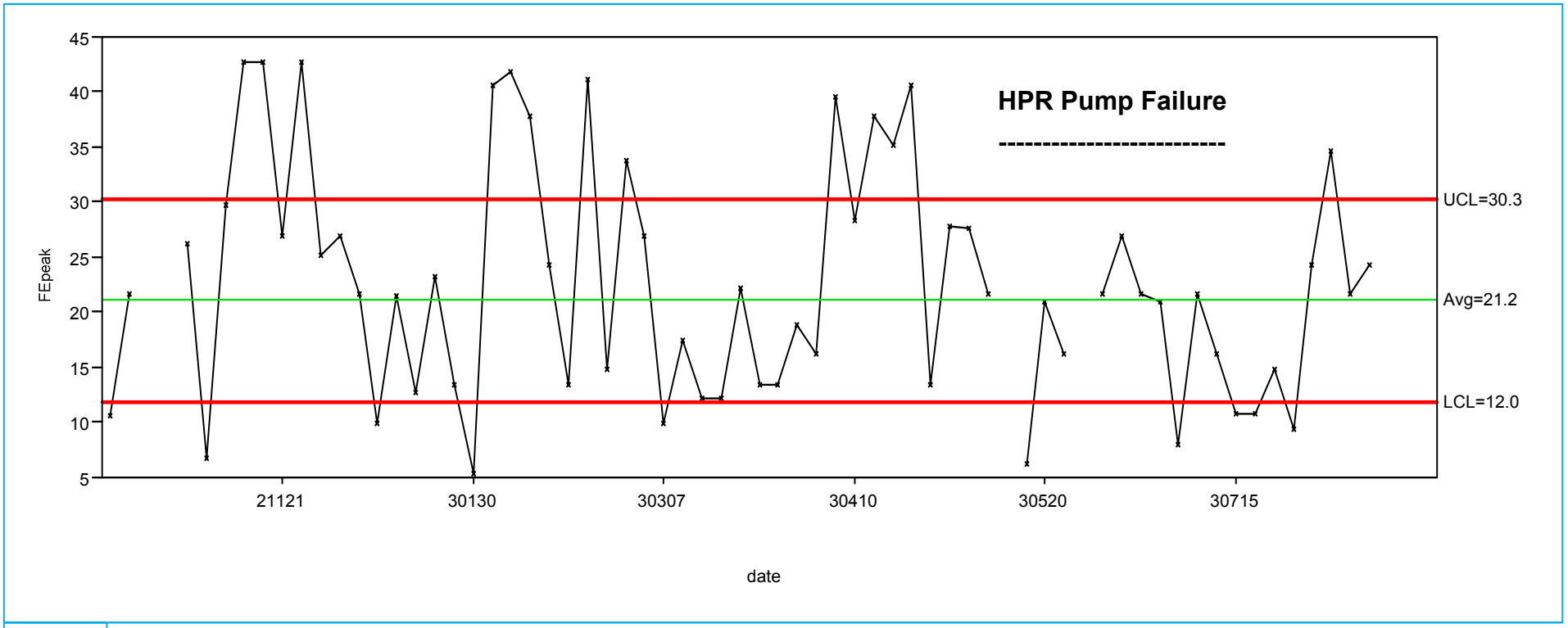
N – 21

Mean – 26.94

Std Dev – 8.74

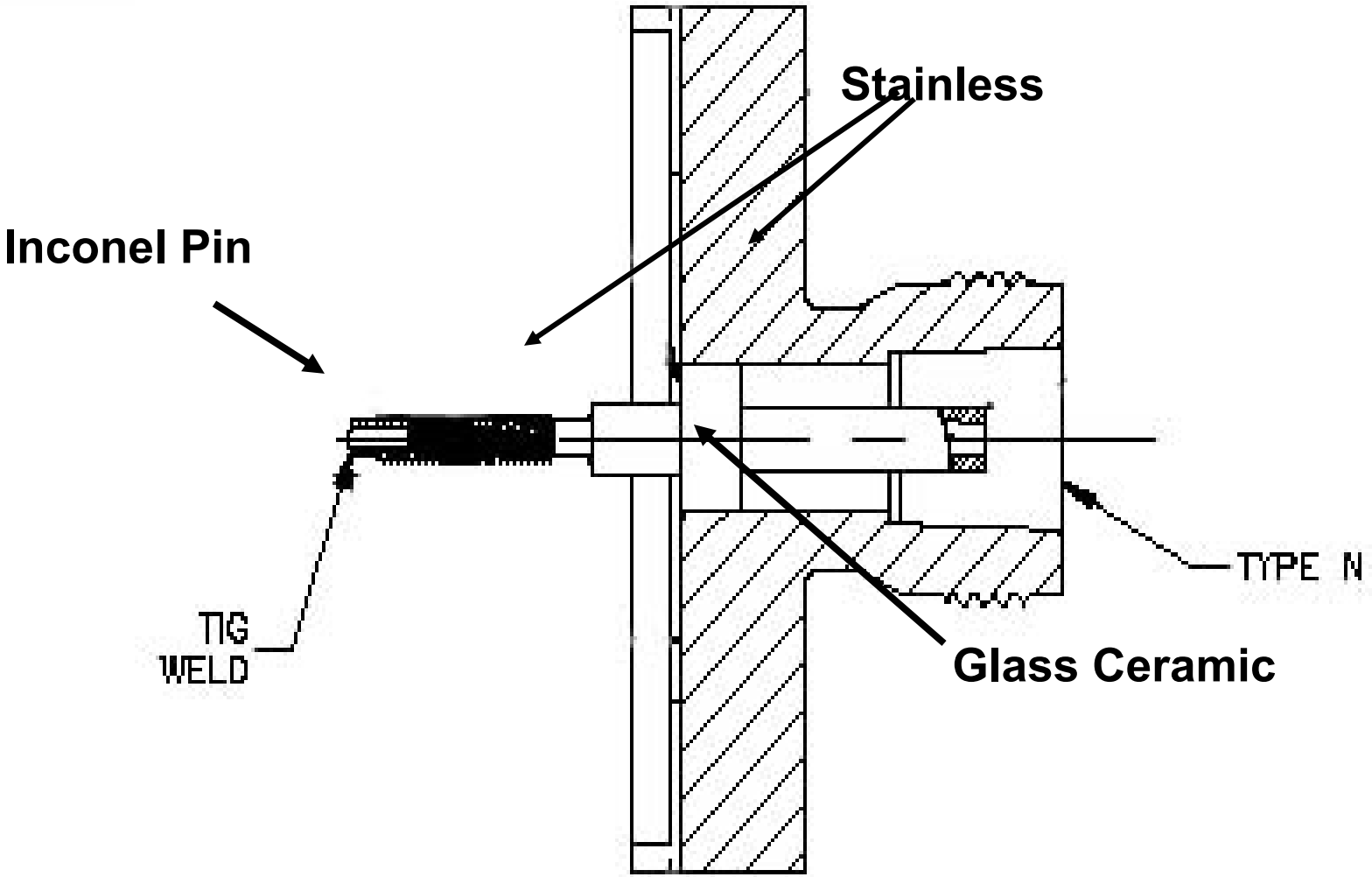
Field Emission Onset Chronologically

Field Emission Onset Vs Time

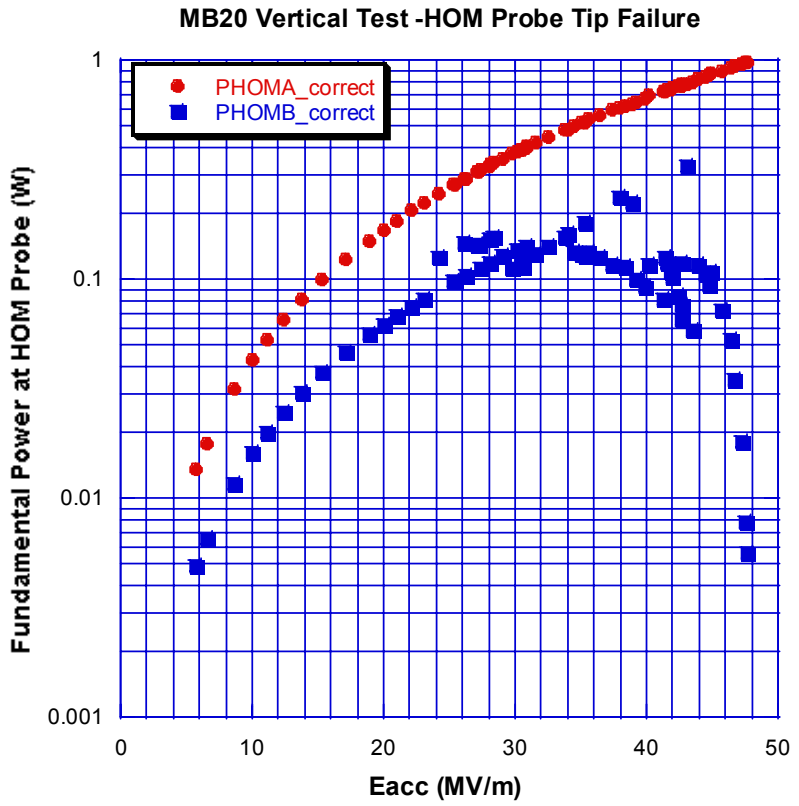


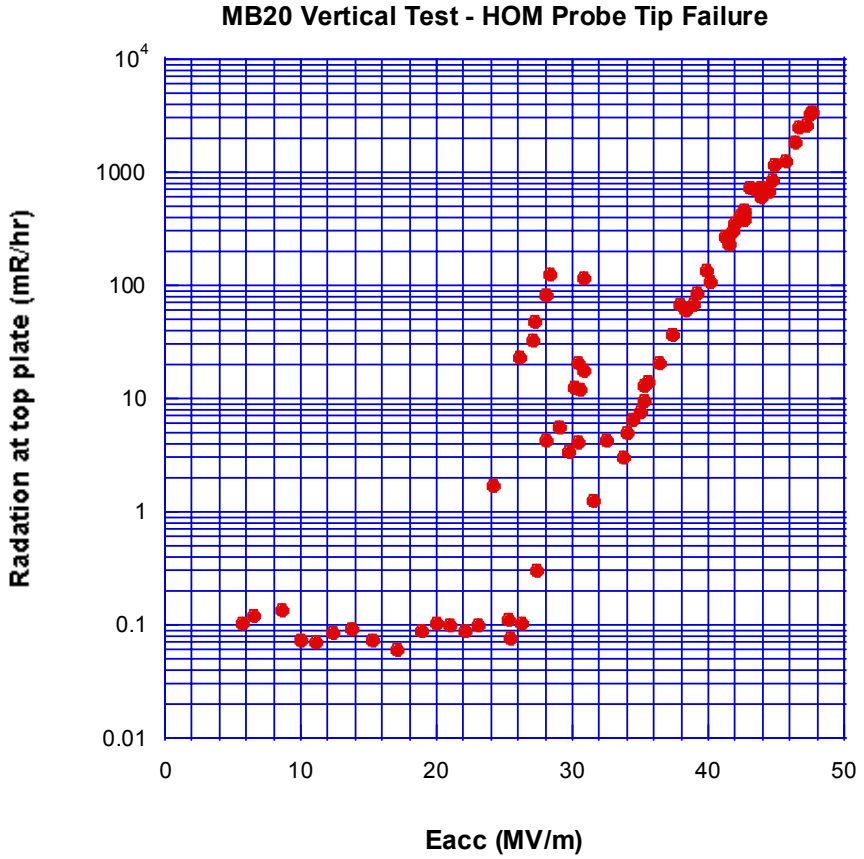
FEpeak

HOM Probe Feed-thru Heating

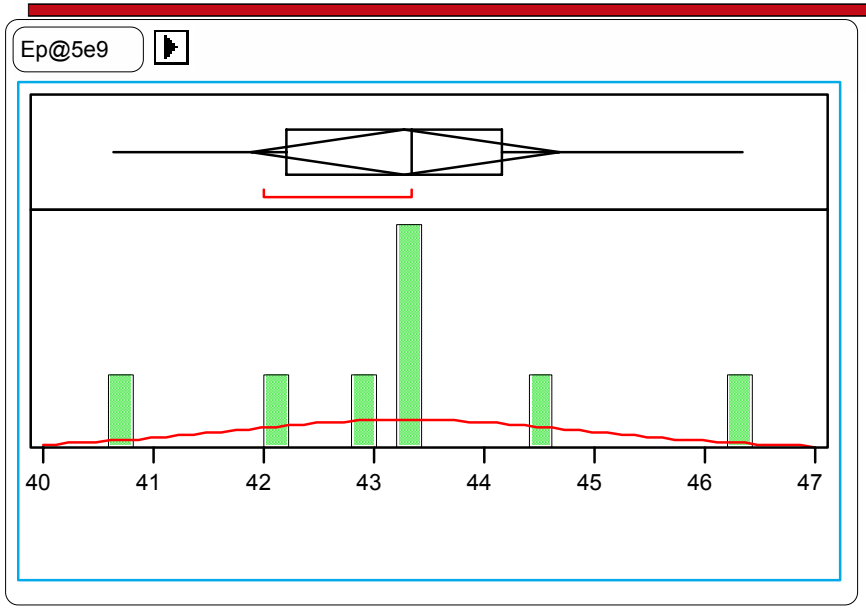


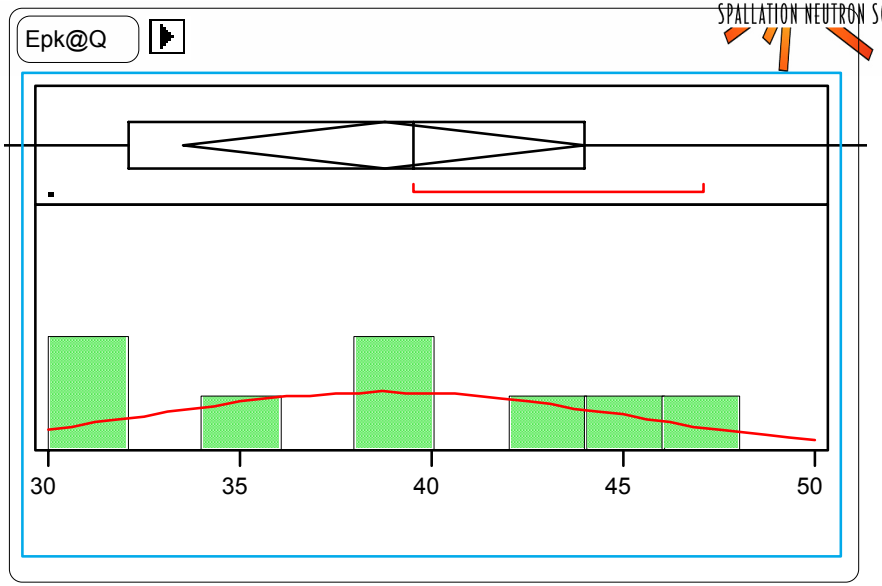
HOM Copper Probe Tip Melted During Vertical RF Testing





Comparison of Module and Vertical Cavity Results Epk @ Q=5E9





M1-M3 Results (pulsed)

N – 8

Mean – 43.29

Std Dev – 1.66

Vertical Test Results (CW)

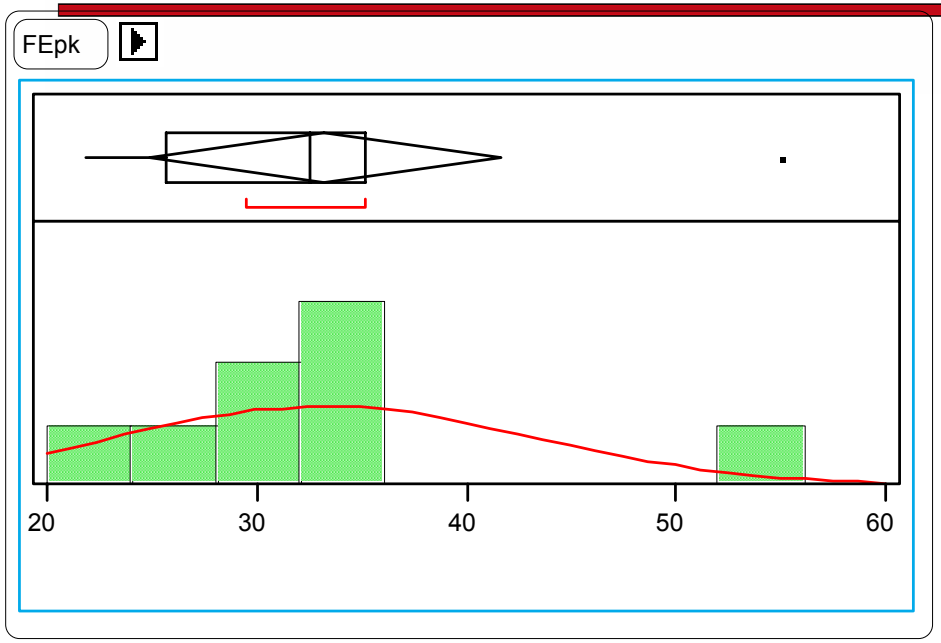
N – 8

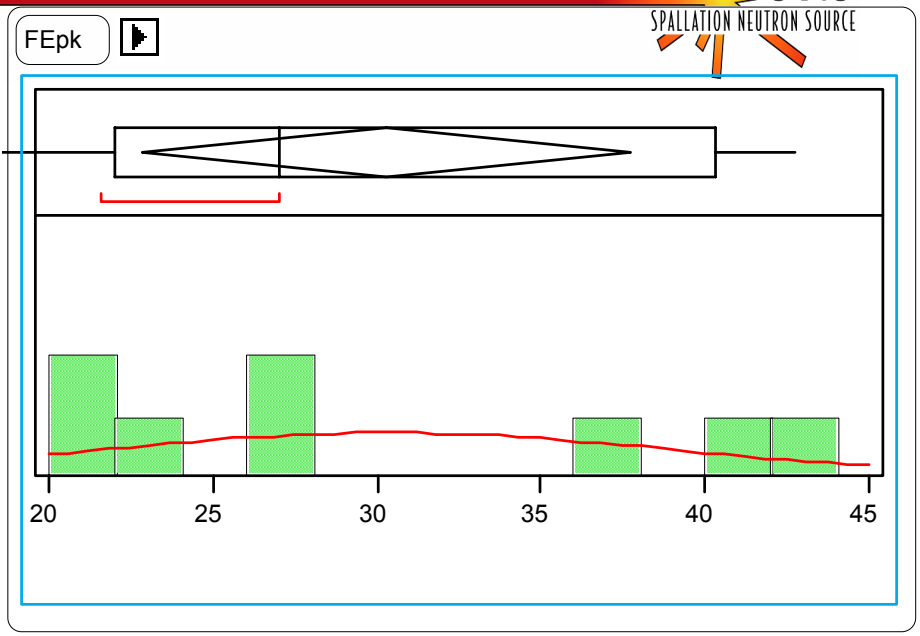
Mean – 38.78

Std Dev – 6.24

Cryomodule Test Results

M1-M3 FE-onset





M1-M3 Cavity Tests (pulsed)

N – 8

Mean – 33.33

Std Dev – 10.04

Vertical Tests (CW)

N – 8

Mean – 30.34

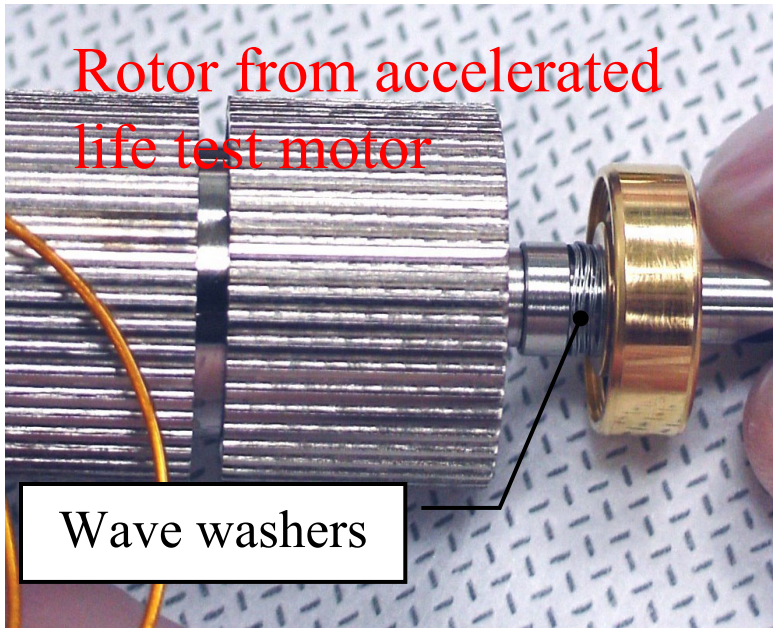
Std Dev – 8.89

Technical Issues With Cryomodule Performance

- Tuner Motor Failures
  - After cooldown of M1 two of the three motors failed
  - Motors replaced after warmup and two additional failures second cooldown
- Vacuum leaks on production runs
  - coupler bellows
  - End Cans

- Vendor production changes after first articles were identified as the reason for failures

Tuner Motor Failures- Comparing SNS Tuner Motor Shafts: Prototype (left) and Production (right)



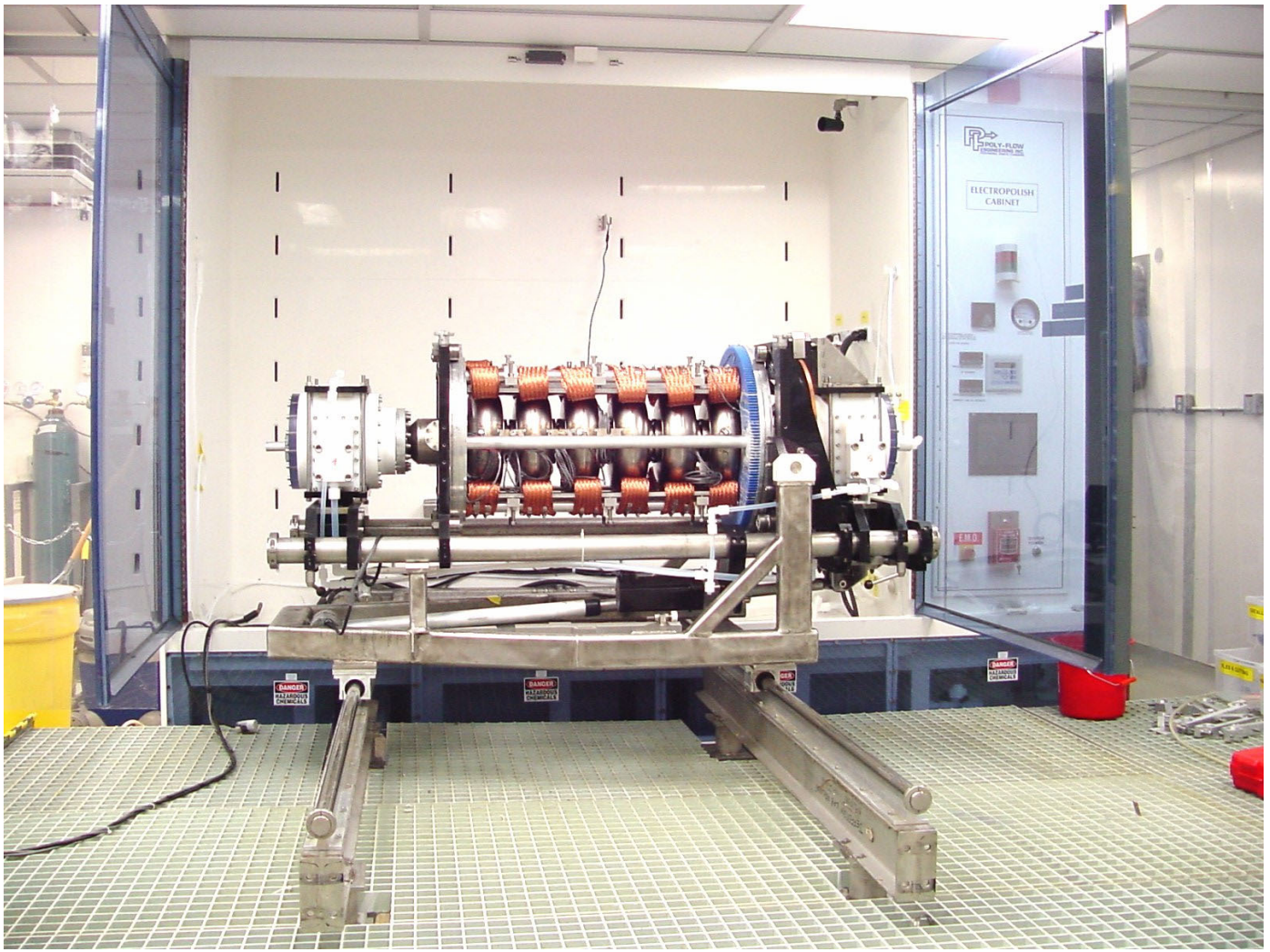
The prototype motor has a series of wavy washers that are used to provide a pre-load on the shaft while allowing compliance during cooldown and operation at 4K.

The production motor has a single wavy washer to the right of the bearing to provide this pre-load and compliance. The compliance is drastically reduce when compared with the prototype motor.

High Beta Cavity Electropolishing Status

- Demonstrated the System Can Meet Production Rates 2 /week
  - Cavities Processed (450 Amps at 15-25 V for 4 hours)
    - 1 Prototype
    - 4 Production High Beta Cavities
  - Three cavities Vertically Tested
    - HB01prototype, HB02,HB04

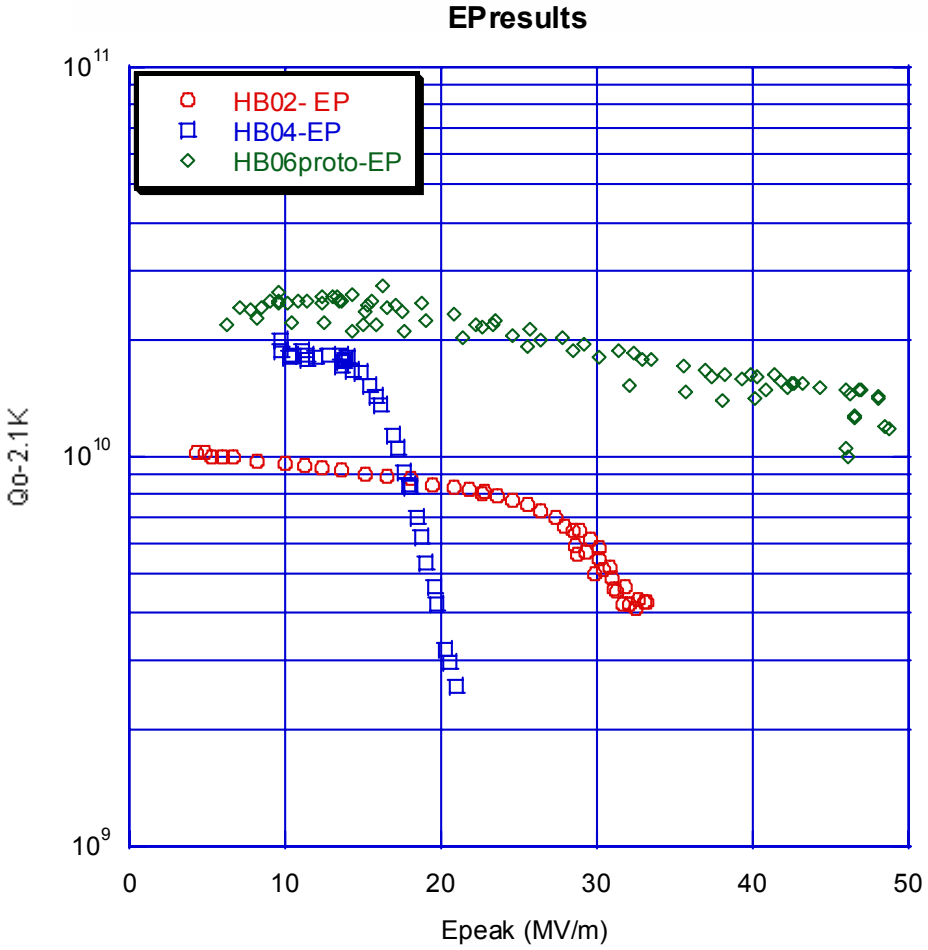
EP Cabinet

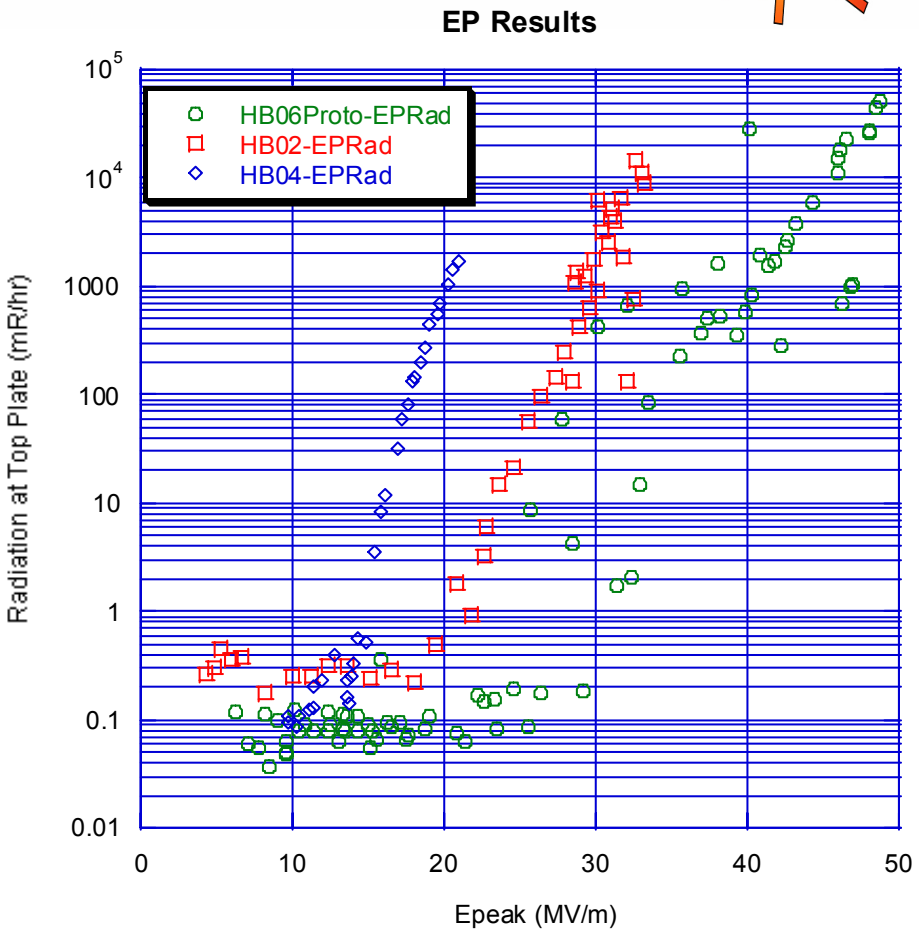


EP Assembly Sequence

- Initial inspection
- Mechanical inspection
- RF tuning
- Degreasing
- Furnace treatment 600C
- EP 4 hours at 450 A
- External rinsing
- HPR 2 hours
- Assembly / HPR 2 hours
- Assembly/evacuation/leaktest
- Bakeout 100C 48 hours
- VTA RF test
- Final tuning
- Helium vessel welding
- RF inspection / Degreasing
- 5um BCP/HPR 2 hours or just HPR 2 hours

Electropolished Cavity Test Results:





Conclusion:

- The Small Details Can Have A Big Impact on Production! (Seals,Probes,Motors,Vacuum Components)
- Field Emission is Still A Major Challenge!!!
- No Degradation of Cavity Performance from Vertical to Cryomodule Testing
- Electropolish Tests Just Beginning!