Crab Cavity Testing results from CERN SM18

Testing Team

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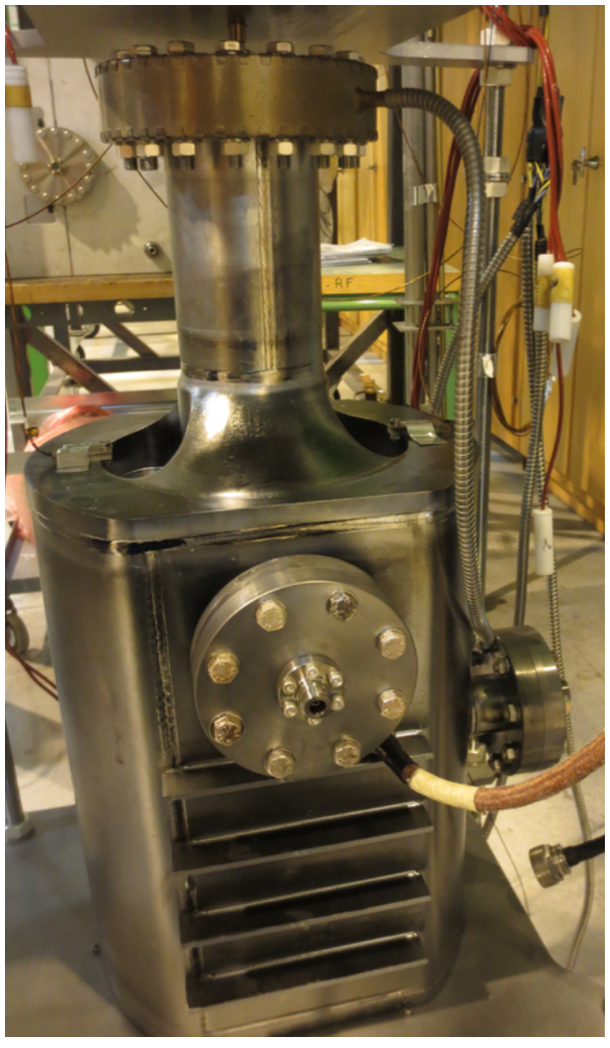
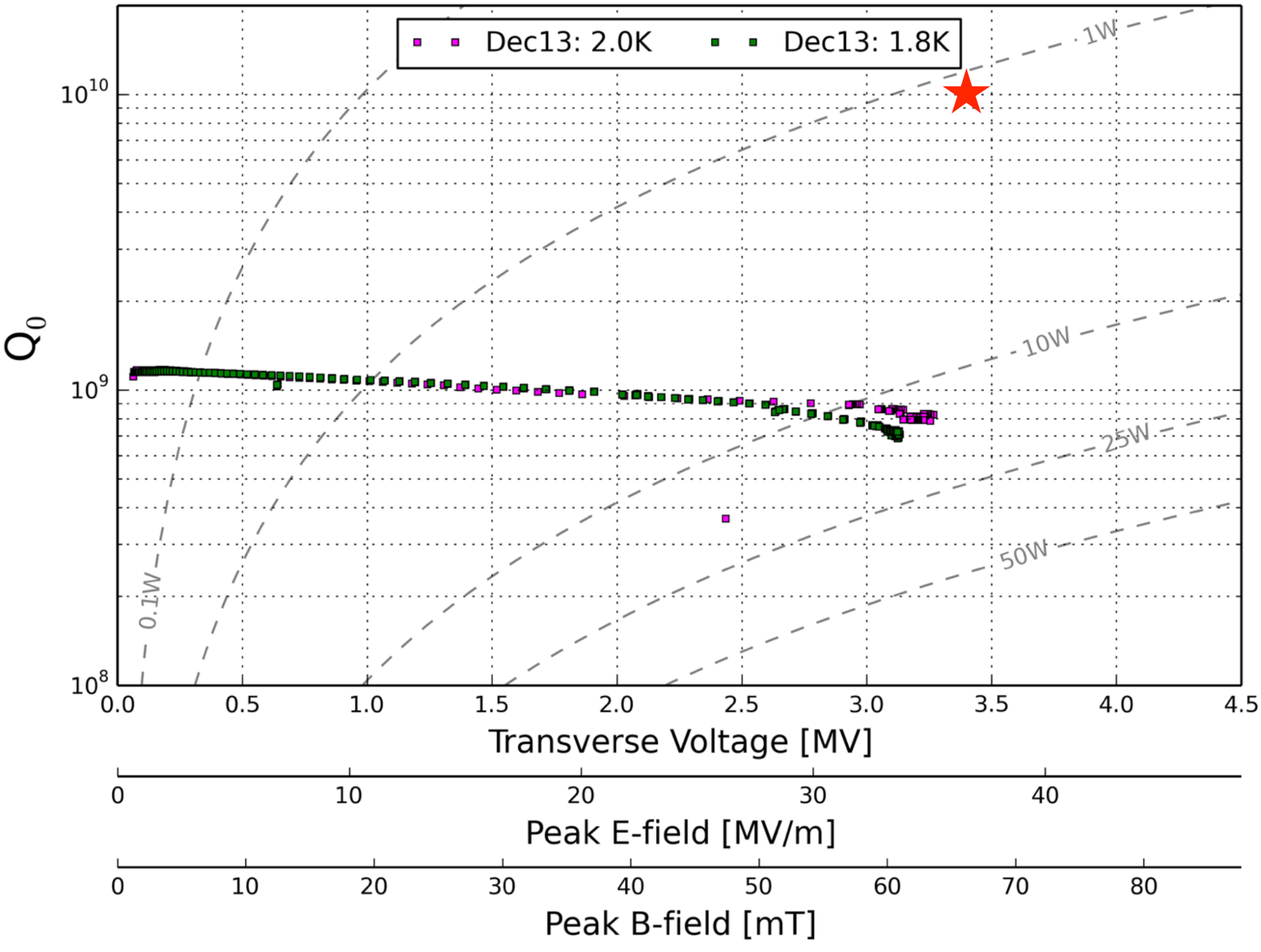
Acknowledgements

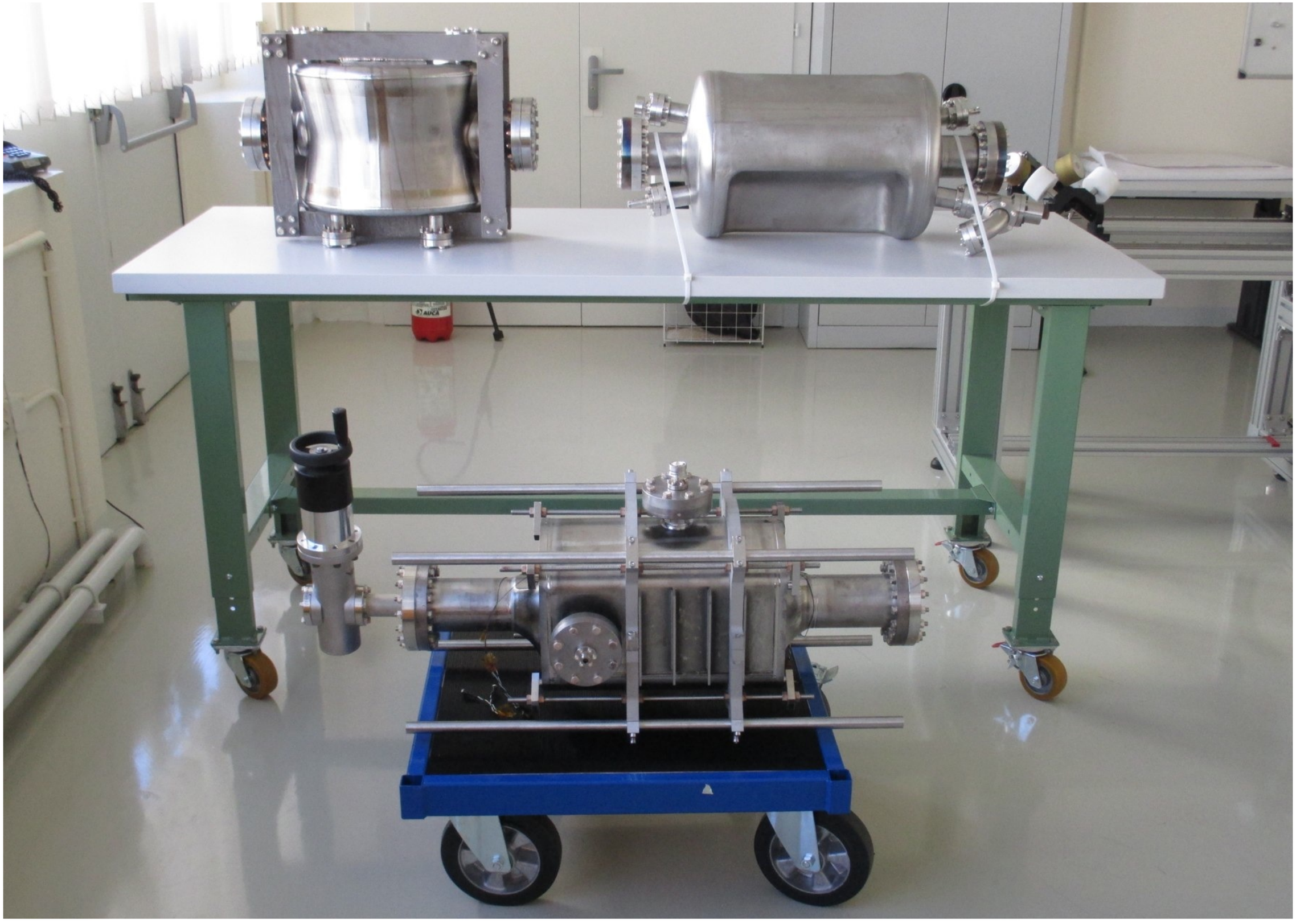
Rama Calaga, Silvia Verdu Andres, Jean Delayen, Qiong Wu, Sarah Aull, Pierre Maesen, Mathieu Therasse, Gabriel Pechaud, Max Gourragne, Wilhelmus Vollenberg.

SM18: Our 1st Crab Cold Test - UK_4Rod





The 3 Proof of Principle Crab Cavity Designs



SM18 Crab Cavity Cold Tests

- **Motivation:**
  - Calibrate CERN's SM18 stand against ODU and BNL results
  - Learn from comparison of techniques and procedures between groups

- **PoP Crab cavities used for comparison**
  - **UK4R**: Our "first test" test cavity: several construction features
  - **RFD:** shipped "Ready to Test"
  - **DQW:** shipped "Almost ready to test" => flanges needed changing

- **RF Cold Tests performed at 2K in CW mode (ie not pulsed)**

- **Location**
  - Cold testing performed in the SM18 V3 cryostat
  - DQW HPR and assembly performed in SM18 ISO4 clean room

Cavity Preparation History

RFD

- **March 2013: RF Test @ JLAB**
  - Bulk BCP – 85 μm
  - Heat treatment: 10 hrs at 600 C
  - Light BCP – ~10 μm
  - High Pressure Rinse – 3 passes
  - Cavity assembly + Cold Test
- **August 2014: RF @ JLAB**
  - Light BCP – 15 μm
  - High Pressure Rinse – 2 passes
  - Cavity assembly with Nb coated beam port blank flanges
  - Low temp bake: 24hrs @ 120 C
- **September 2014**
  - Cavity shipped under vacuum
- **October:**
  - Installed & tested in SM18RFD

DQW

- **Ist BNL Cold Test**
  - Bulk BCP – 150 μm
  - Heat treatment: 10 hrs at 600 C
  - Light BCP – 30 μm
  - High Pressure Rinse
  - Cavity assembly + Cold Test
- **2nd BNL Cold Test**
  - BCP of 40 μm + HPR
  - 120 C bake for 24 hrs
  - Cold tested
  - Light BCP (40 um). HPR at ANL.
- **July 2014**
  - Cavity shipped under Nitrogen
- **September: Cavity ports not clean**
- **November:**
  - HPR in SM18: 100bar -2 passes
  - Installed & tested in SM18

RFD: Insert preparation

- **Agreement with Jean: “Cavity should see no European air”**
  - Cavity installed on insert, pumping line baked before opening cavity valve

RFD: Connection of vacuum pumping line

Done by C.Jarrige
The 16/10/2014

RFD: Connection of Pumping Line - Pressure Profile at 300K

*Pressure in the cavity : **P = 1.10^{-7}mbar***

opening valve

Swith ON bake out Cryostat pumping line V3+RFDcrab valve closed

stop bake out

1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08

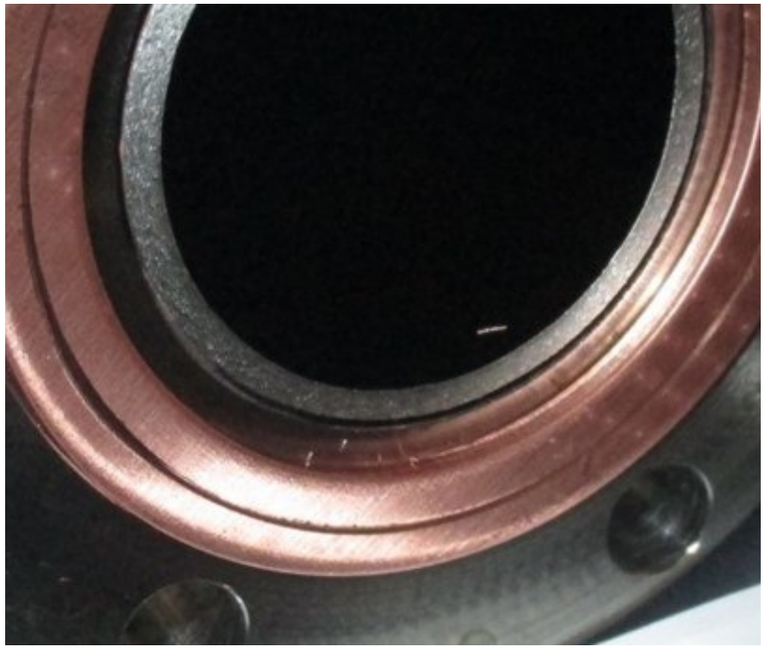
pressure mbar

0
300

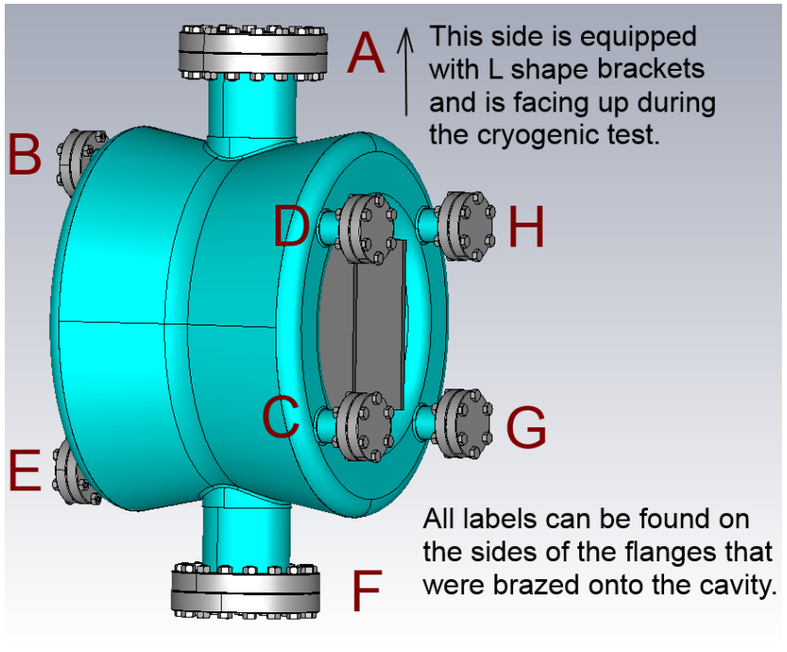
Time (min)

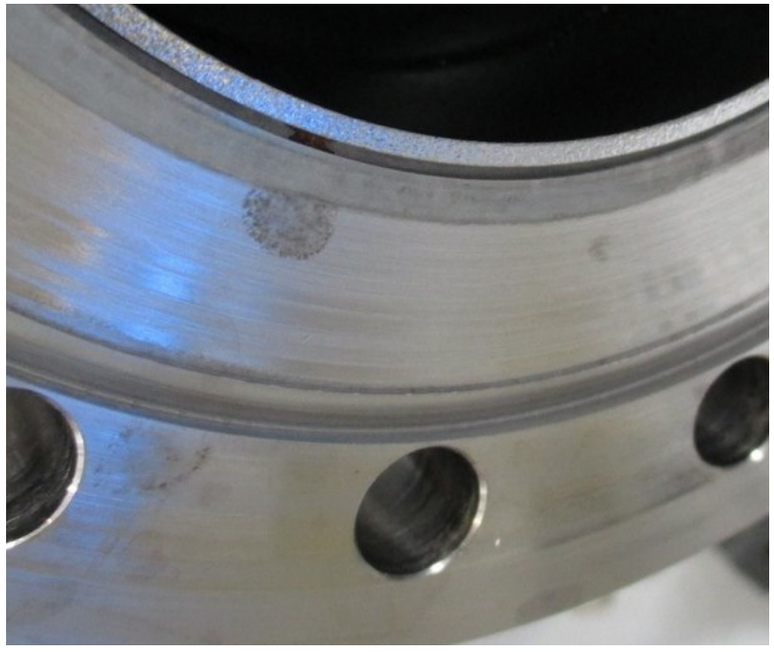
Connection of pumping line not yet ideal

DQW: Preparation Issues



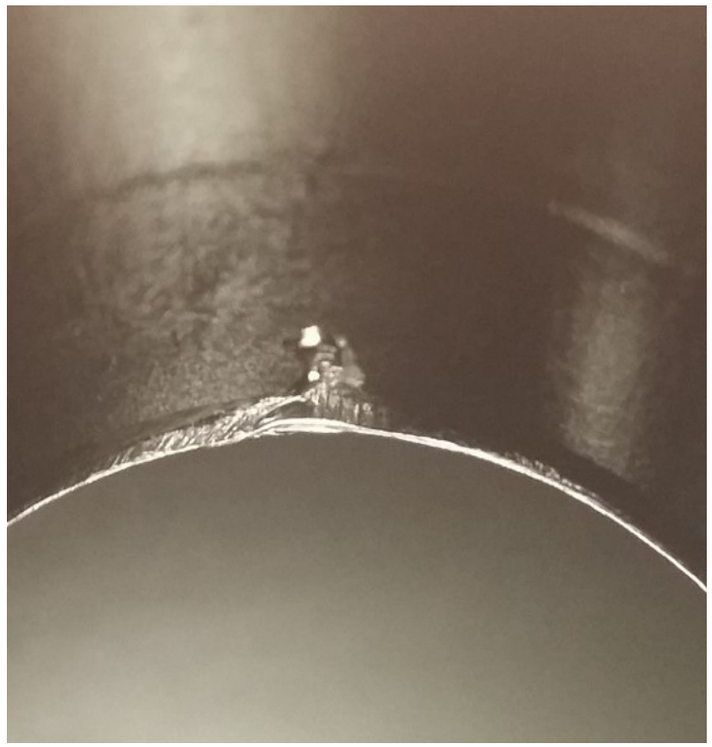
Material inside ports



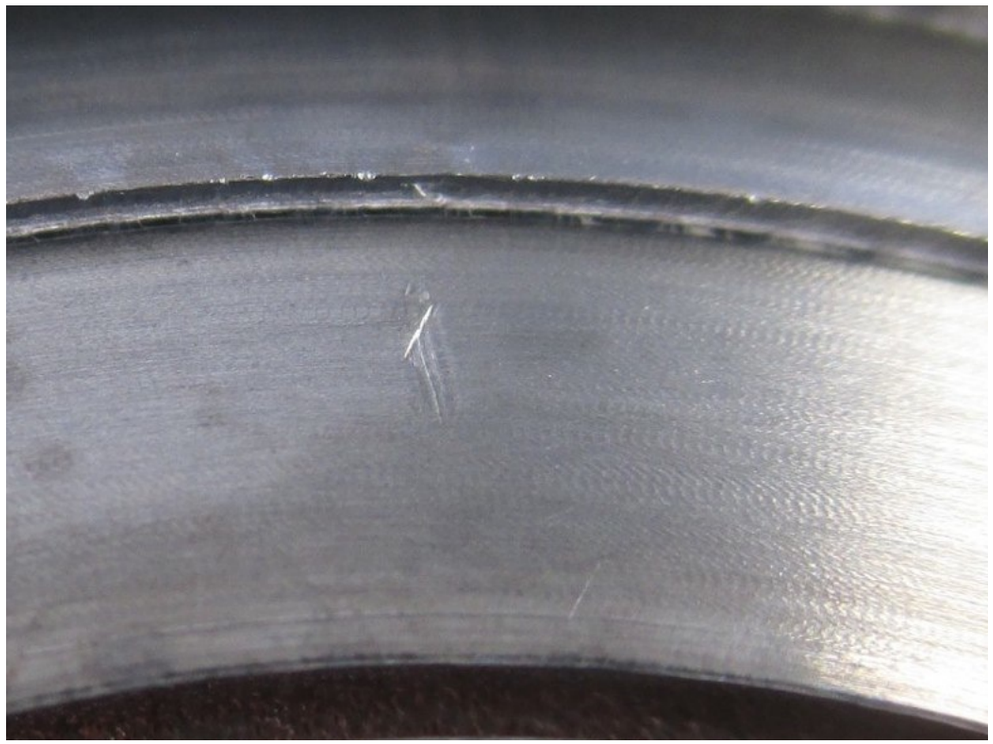


Flange surface

Flange check

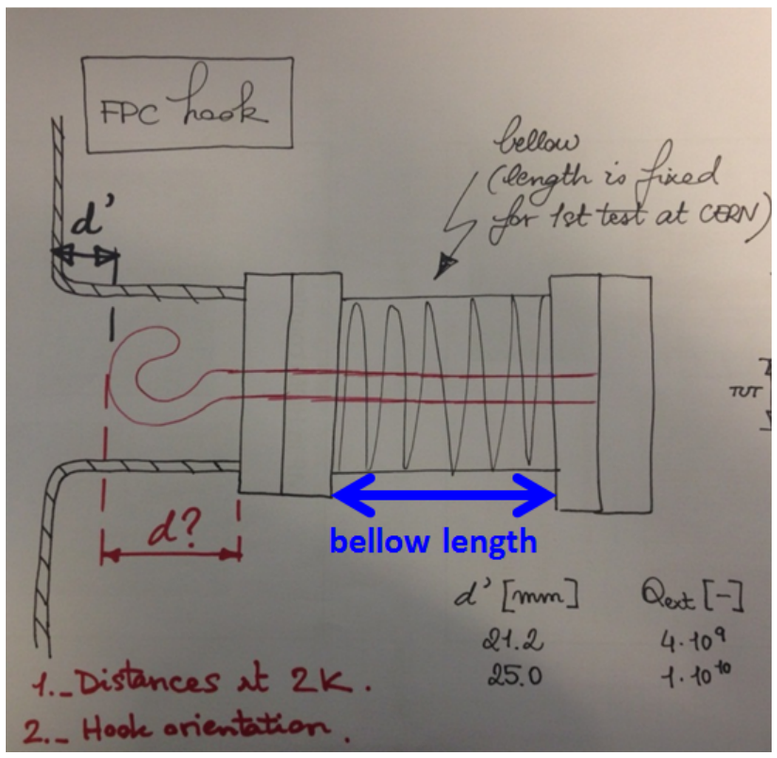


Inside FPC port



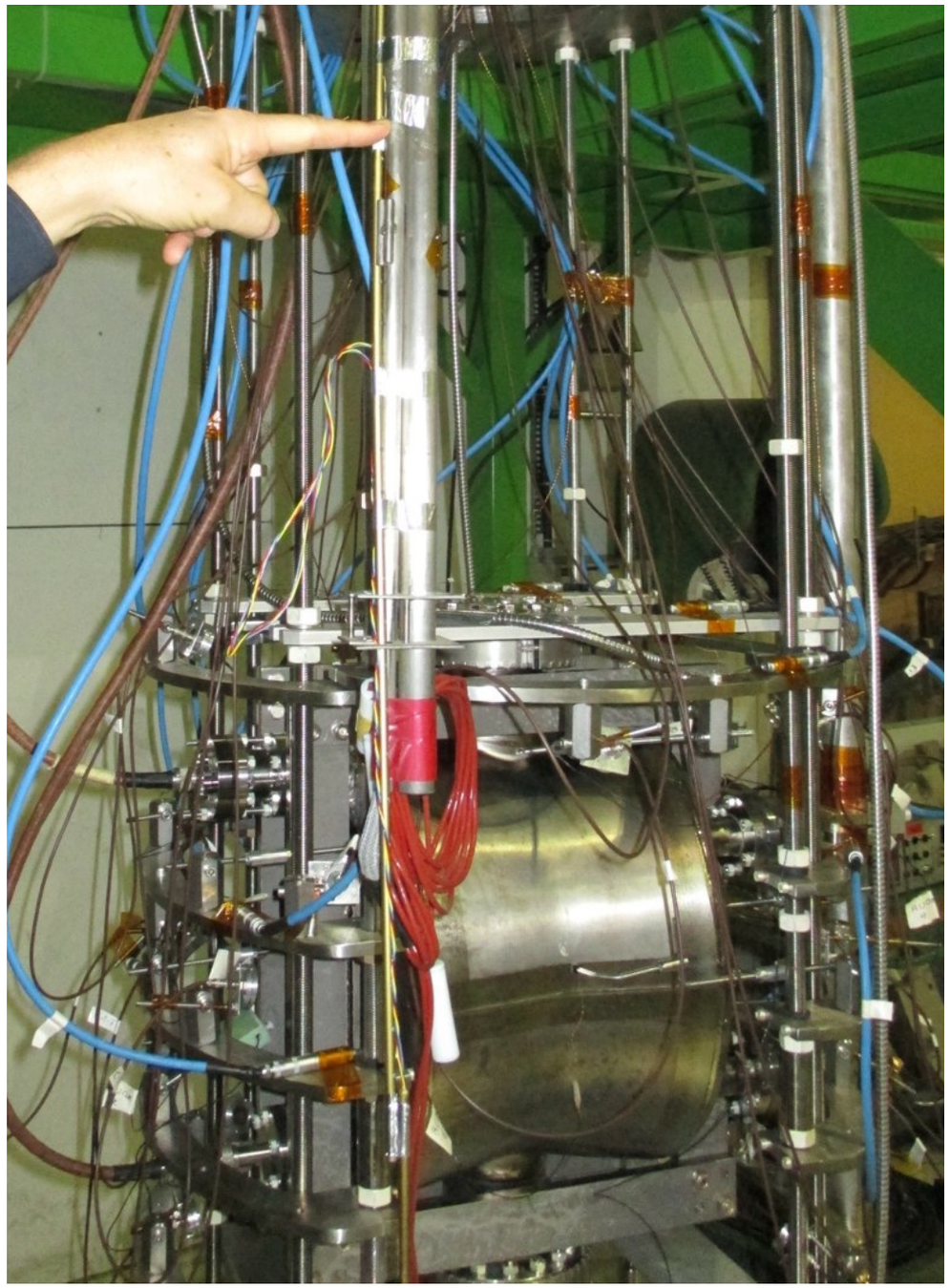
Knife Edge

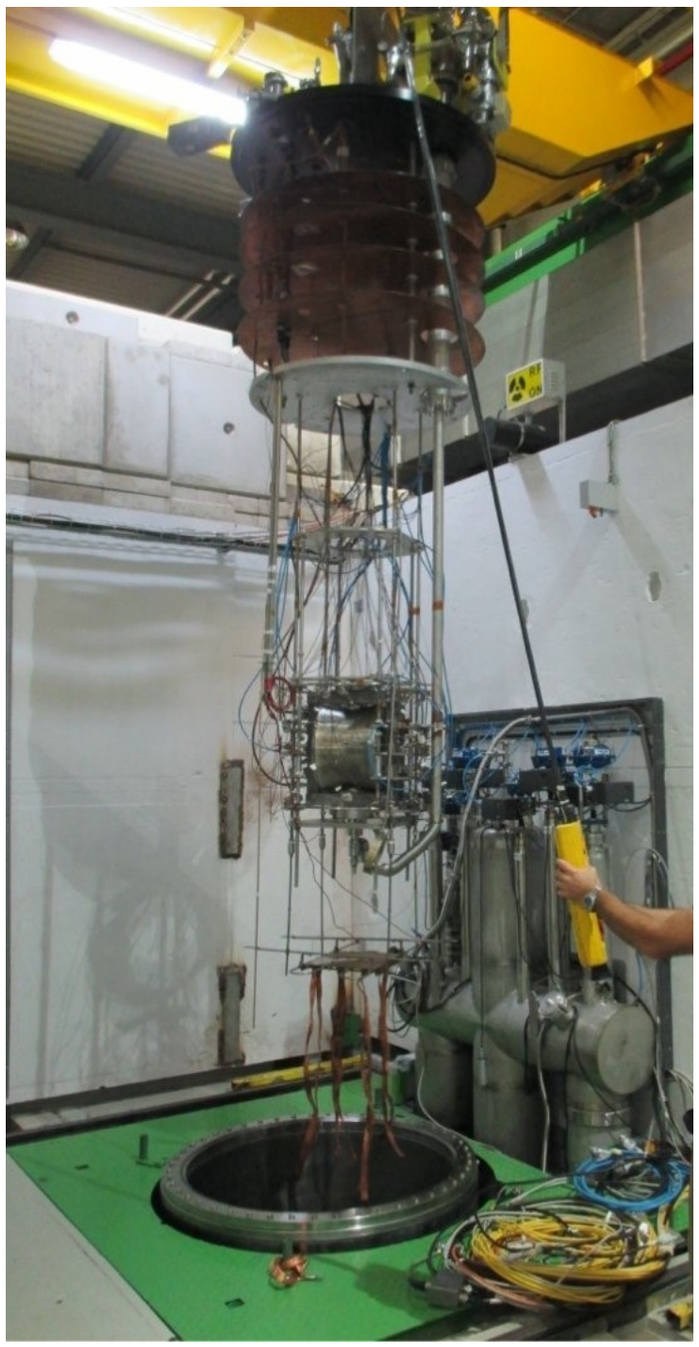
DQW Preparations



New coating setup: No more evidence of Nb peel off

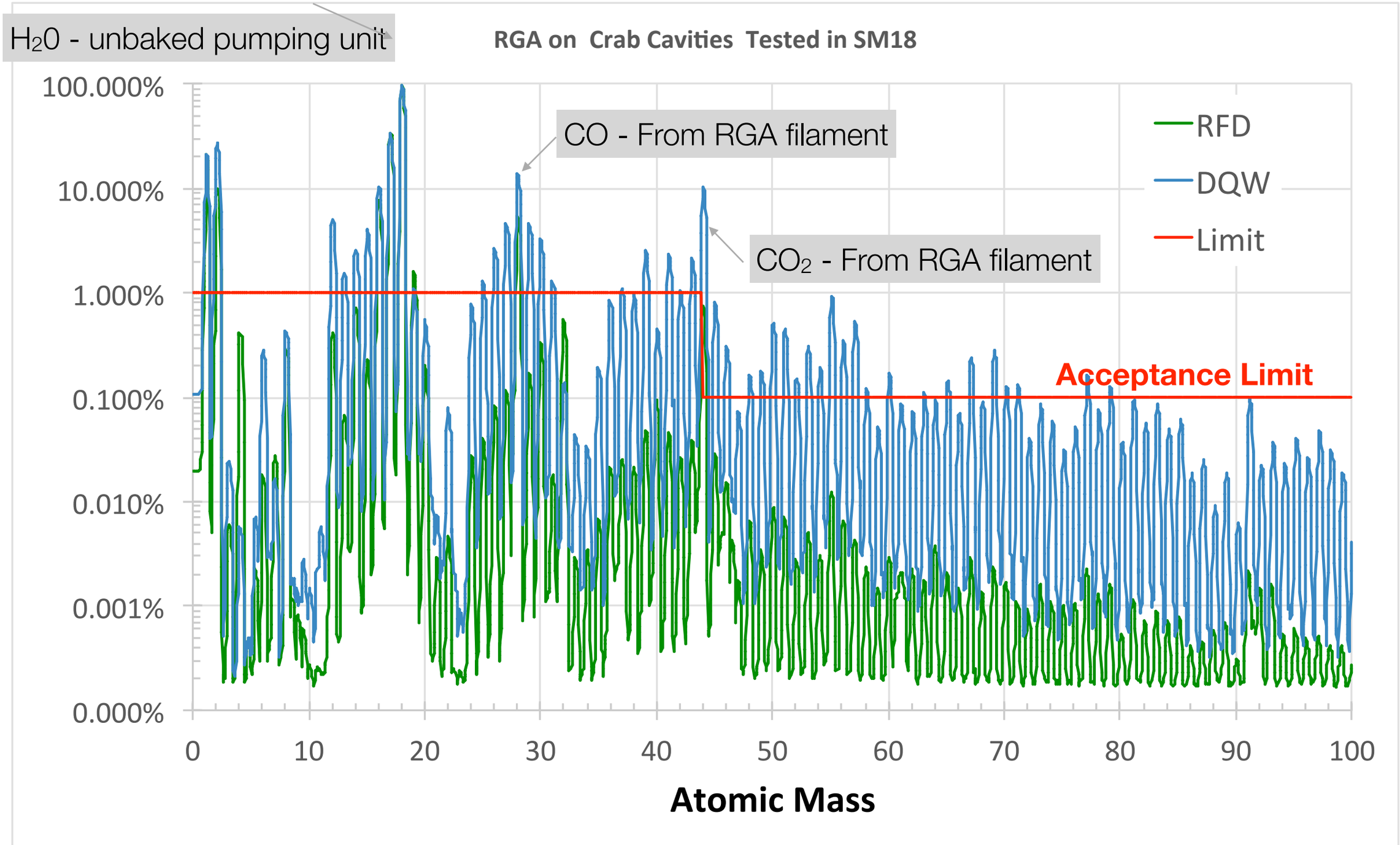
DQW: Insert preparation





Check: Residual Gas Analysis of Cavity Vacuum

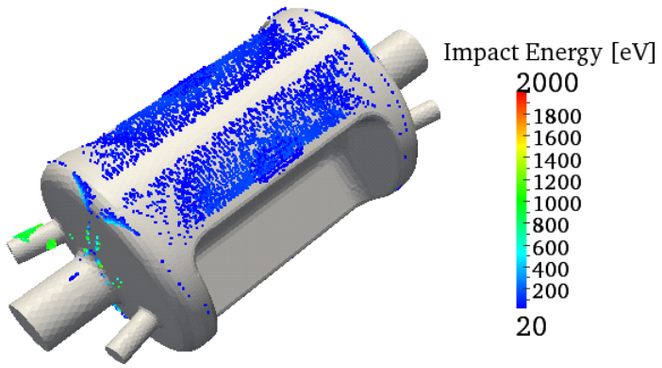
- **RFD: RGA shows acceptable levels in Cavity vacuum**
- **DQW: RGA showed Hydro carbons at limit of acceptable level**

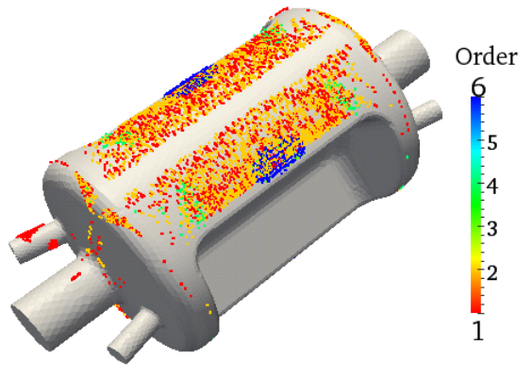


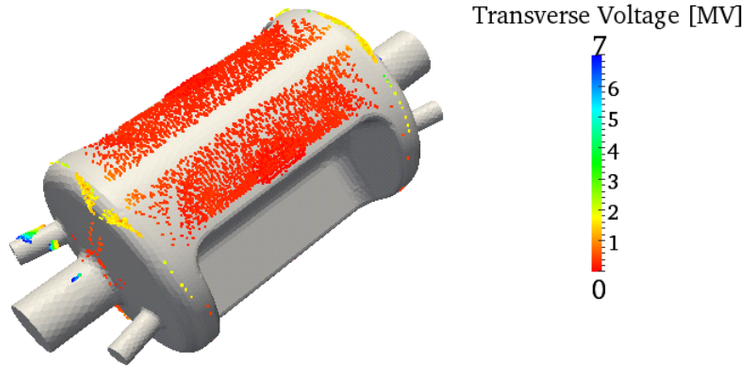
Cold Test Measurements

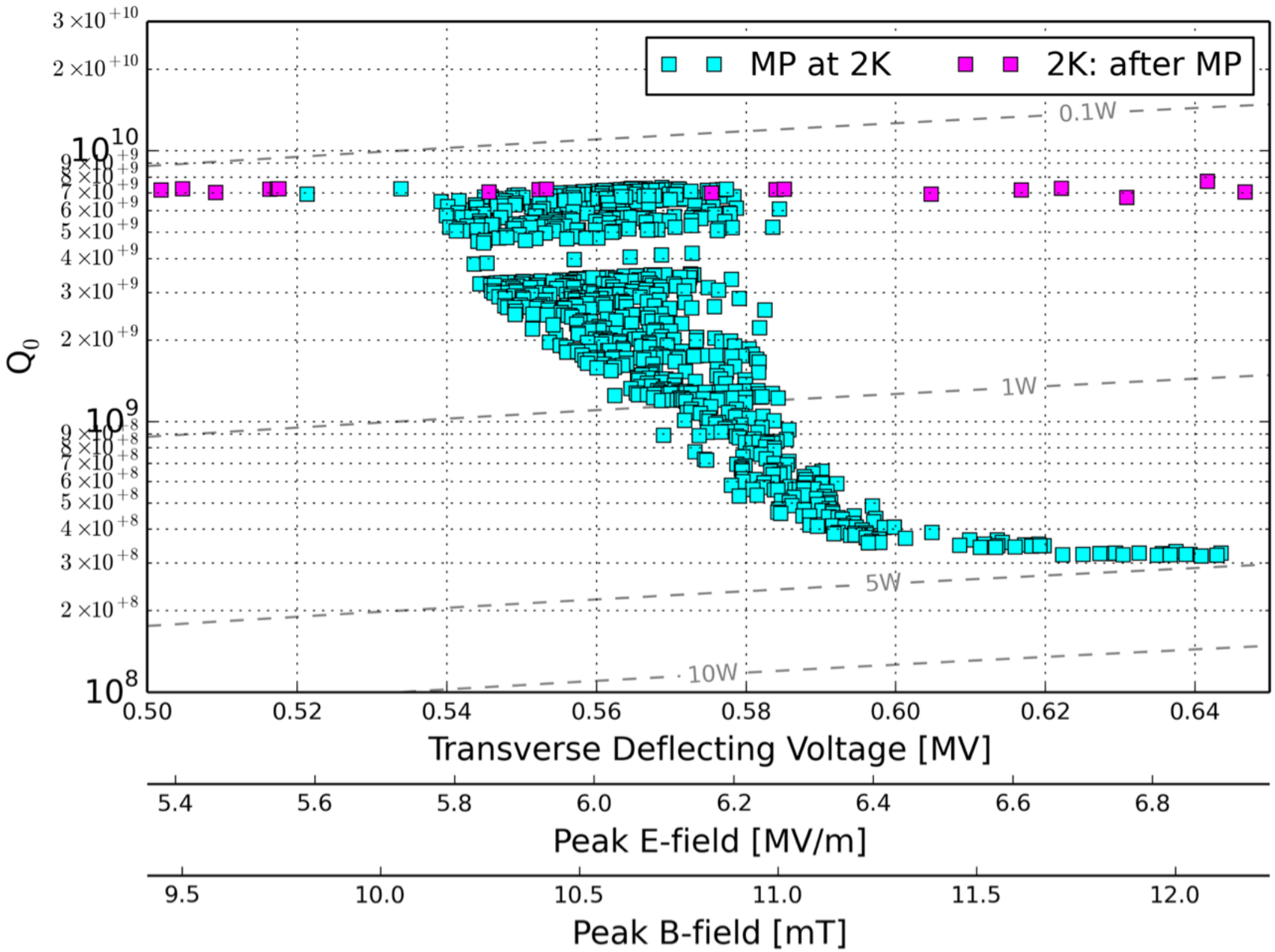
- **RFD Cold Test**
  - Multipacting processing
    - Initial Q0 vs V scan
  - RF conditioning
    - Q0 vs V scan
  - Thermal Cycle
    - Q0 vs V scan
  - Helium Processing
    - Q0 vs V scan
  - Warm up above lambda pt
    - Q0 vs V scan
  - Warm up
- **Cavity test finished**
  - Test Duration:10 days
- **DQW Cold Test**
  - Multipacting processing
    - Initial Q0 vs V scan
  - RF conditioning
    - Q0 vs V scan
  - Helium Processing
    - Q0 vs V scan
  - ….
- **Tests presently ongoing**
  - Testing start: 14 November 2014

RFD Multipacting





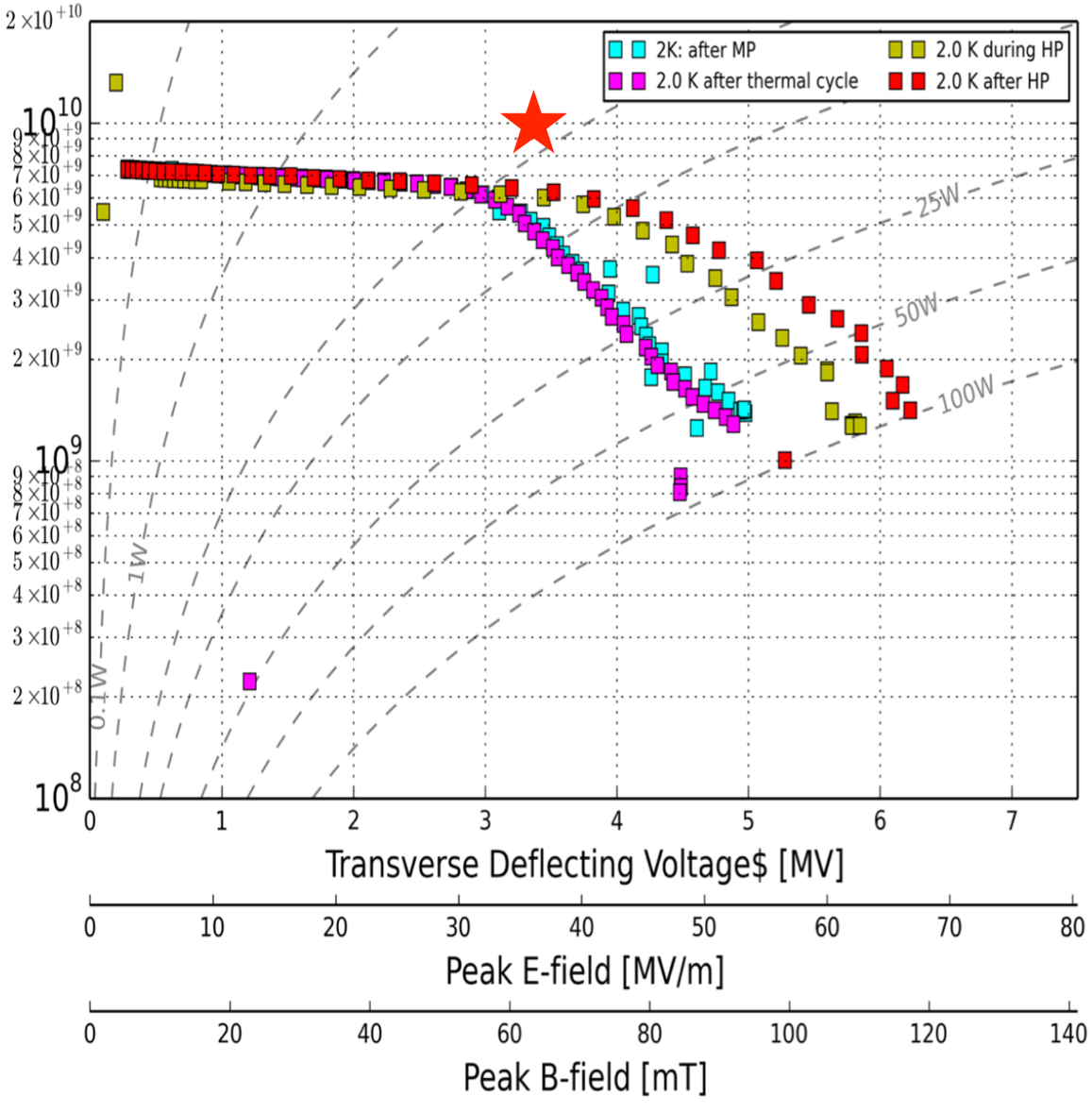


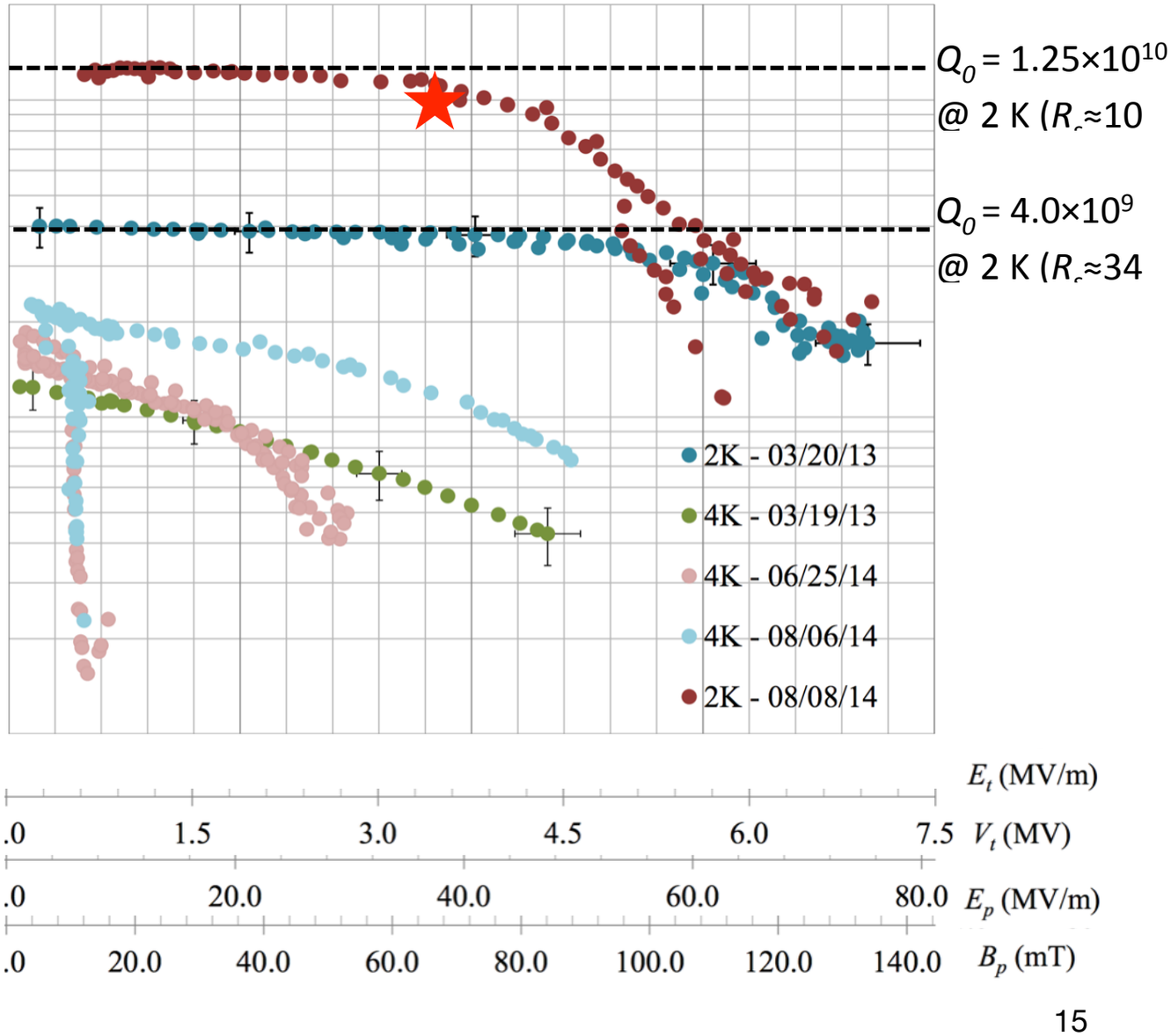


- **Conditioned away in half an hour by gradual increase in power**
- **From ODU test: Multipacting expected at ~0.6MV**
- **Matches with what ODU observed**

RFD: Performance

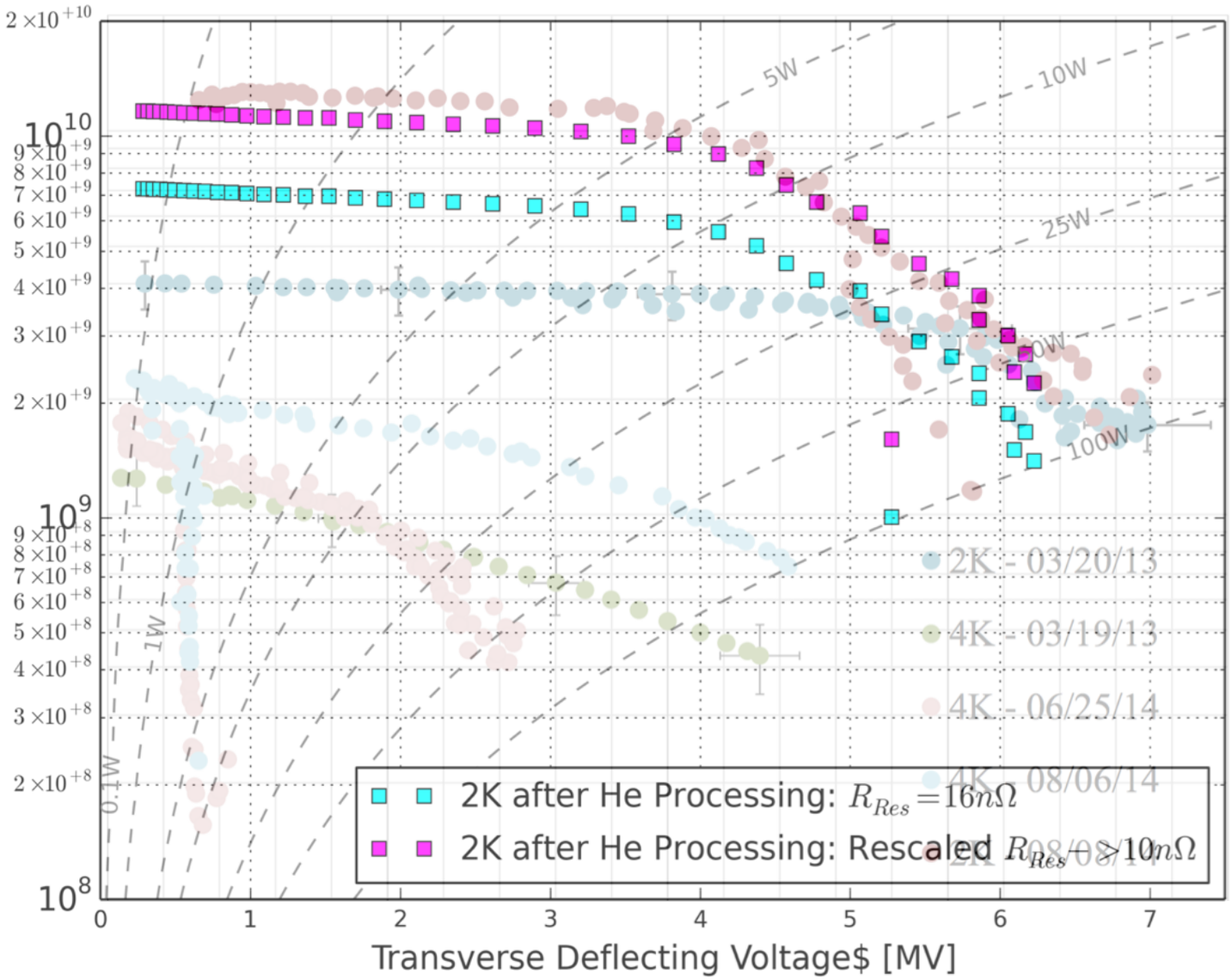
- **CERN Test**
  - Q0 = 7.5 x10^9
  - Residual Resistance = 16 nOhm
  - Max V_T = 6.2 MV
- **ODU/JLAB Test**
  - Q_0 = 1.25 x 10^{10}
  - Residual Resistance = 9.5 nOhm
  - Max V_T = 7.0 MV





RFD: Comparison with ODU results

- **In order to compare, we rescale to same residual resistance**
  - At 2.0 K: Q_0 at low field = 7.26 x10 ^{9} => $R_{Surface}$ =17nΩ => $R_{Residual}$ = 16nΩ
  - Rescale to ODU value of $R_{Residual}$ = 9.5 nΩ => What Q_0 would we have?



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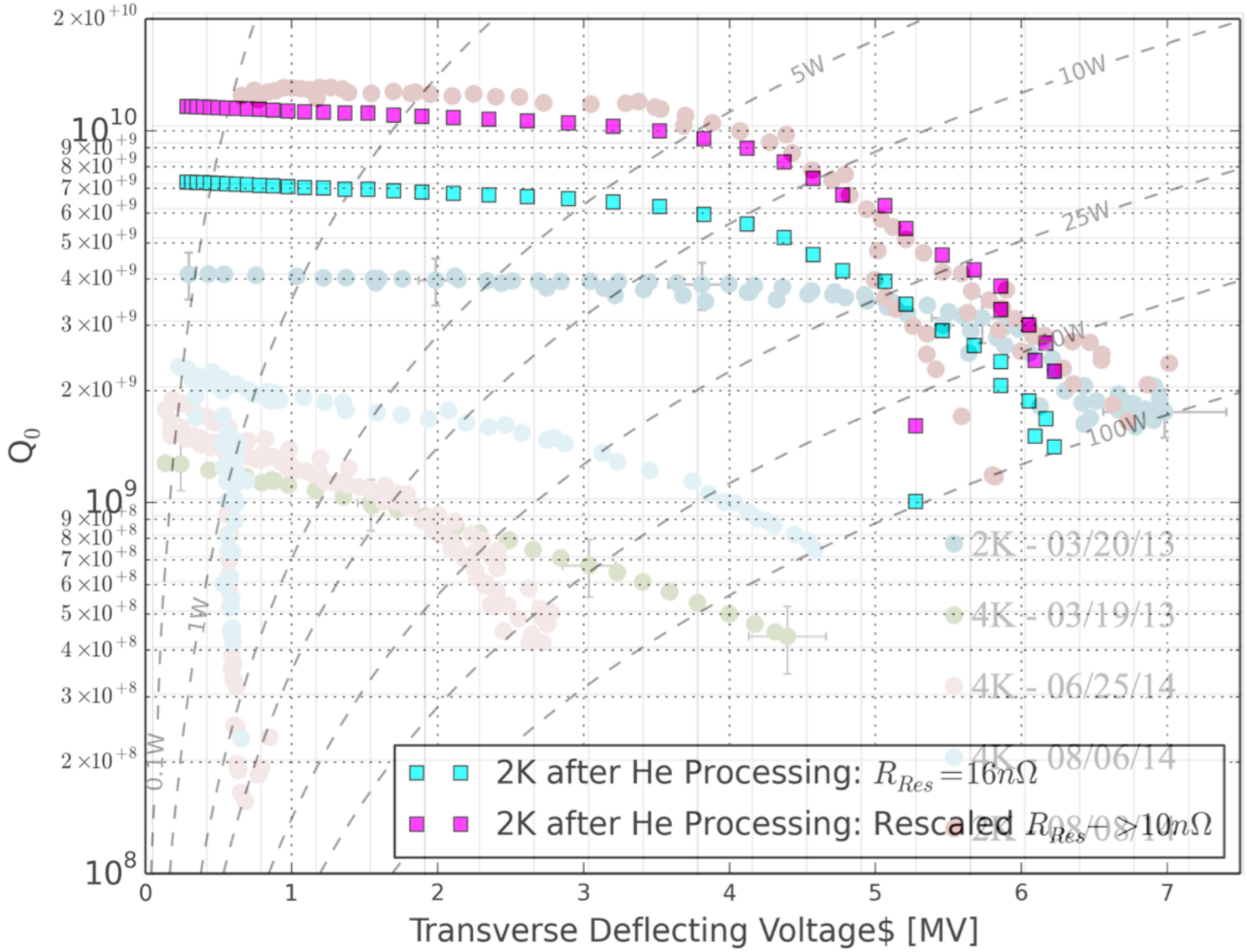
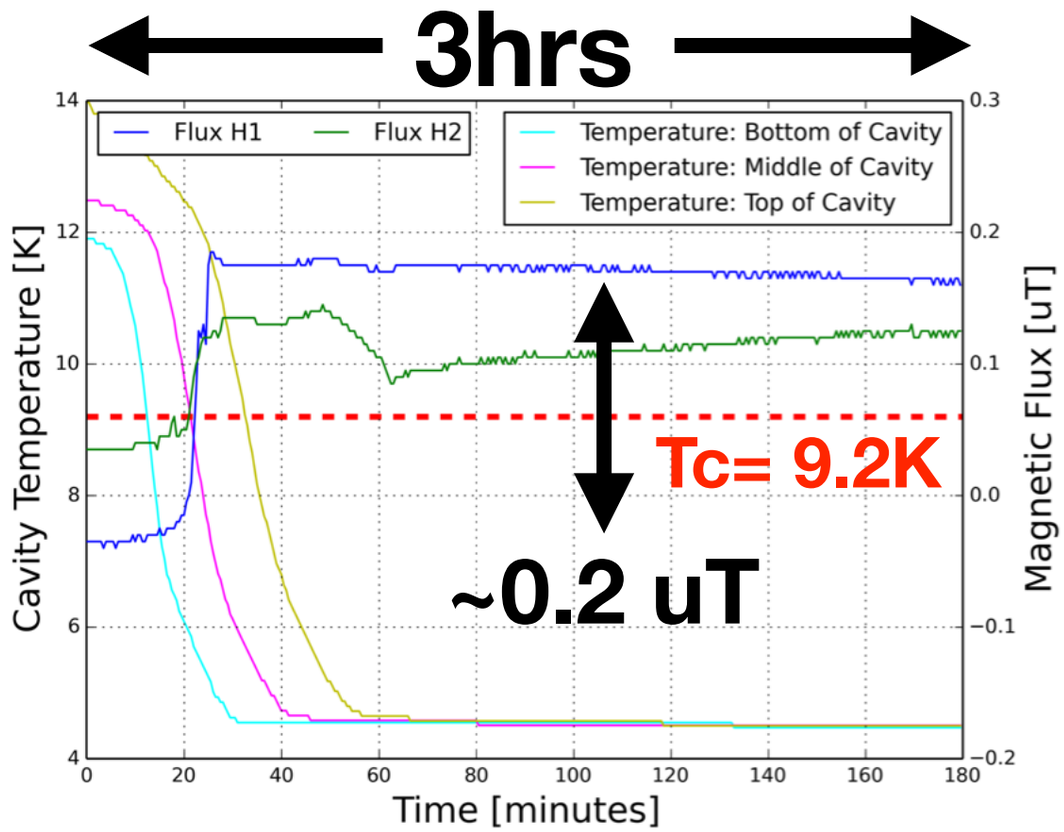
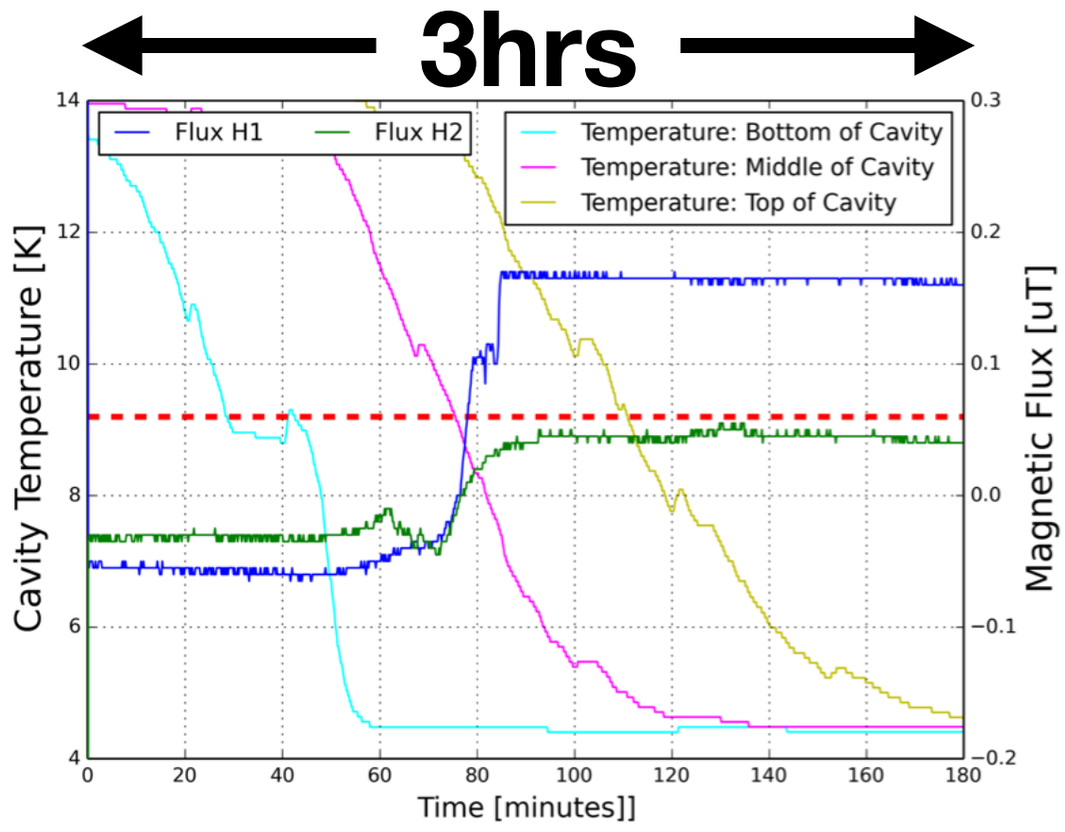


Reasons for higher R_{Res}

- **Peel off of Nb coating on Inox flanges**
  - Discussion with Jean about opening cavity
- **Ambient B-field compensation**
  - Vertical component not fully compensated at T_C
- **Degradation of surface during shipping?**
  - No real evidence

RFD: Transition through T_C & ambient magnetic flux





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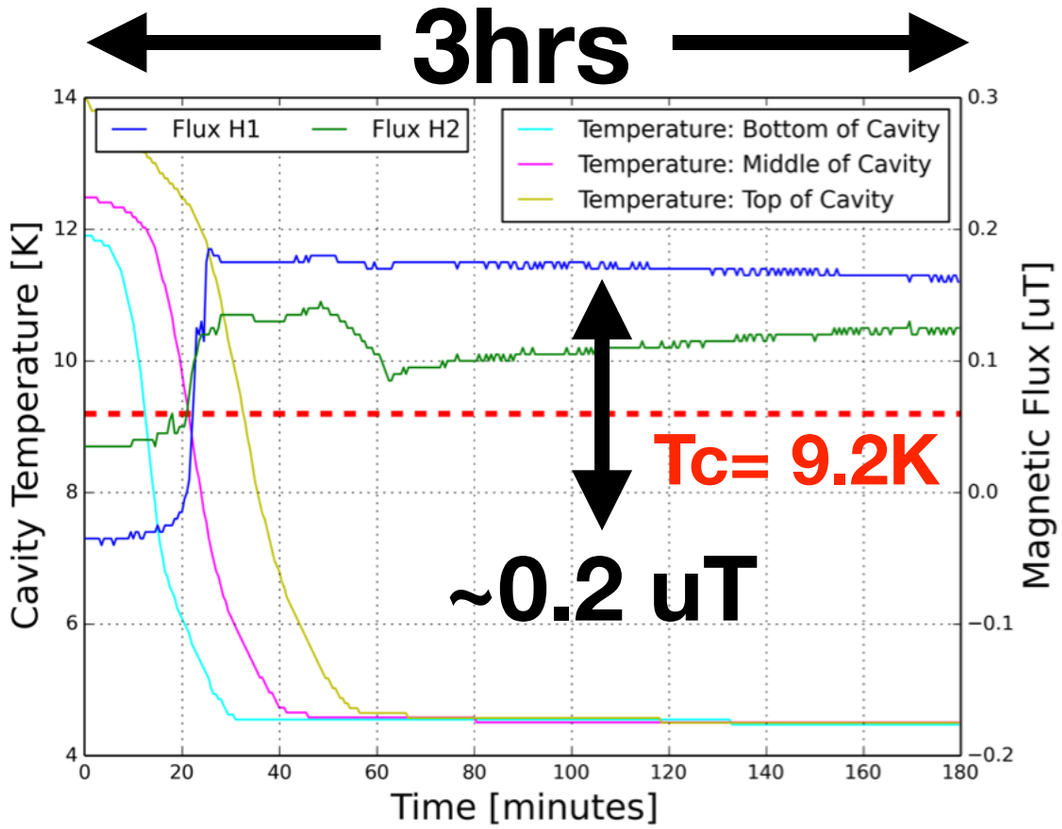
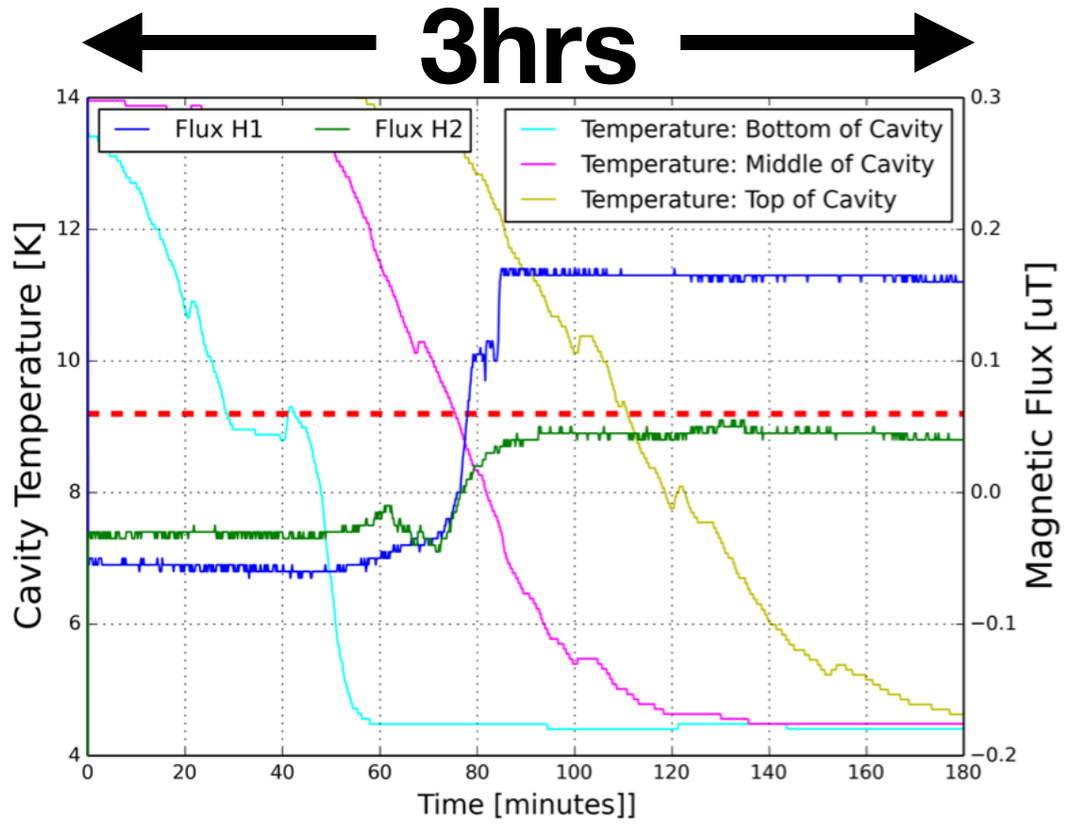
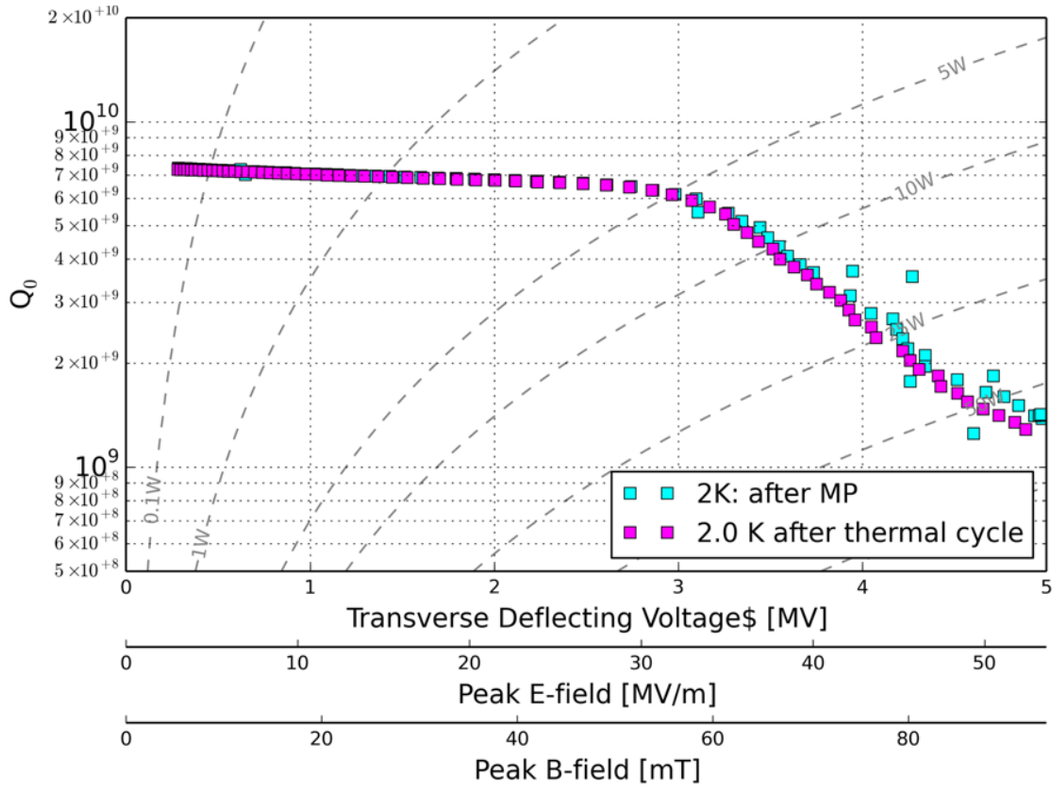
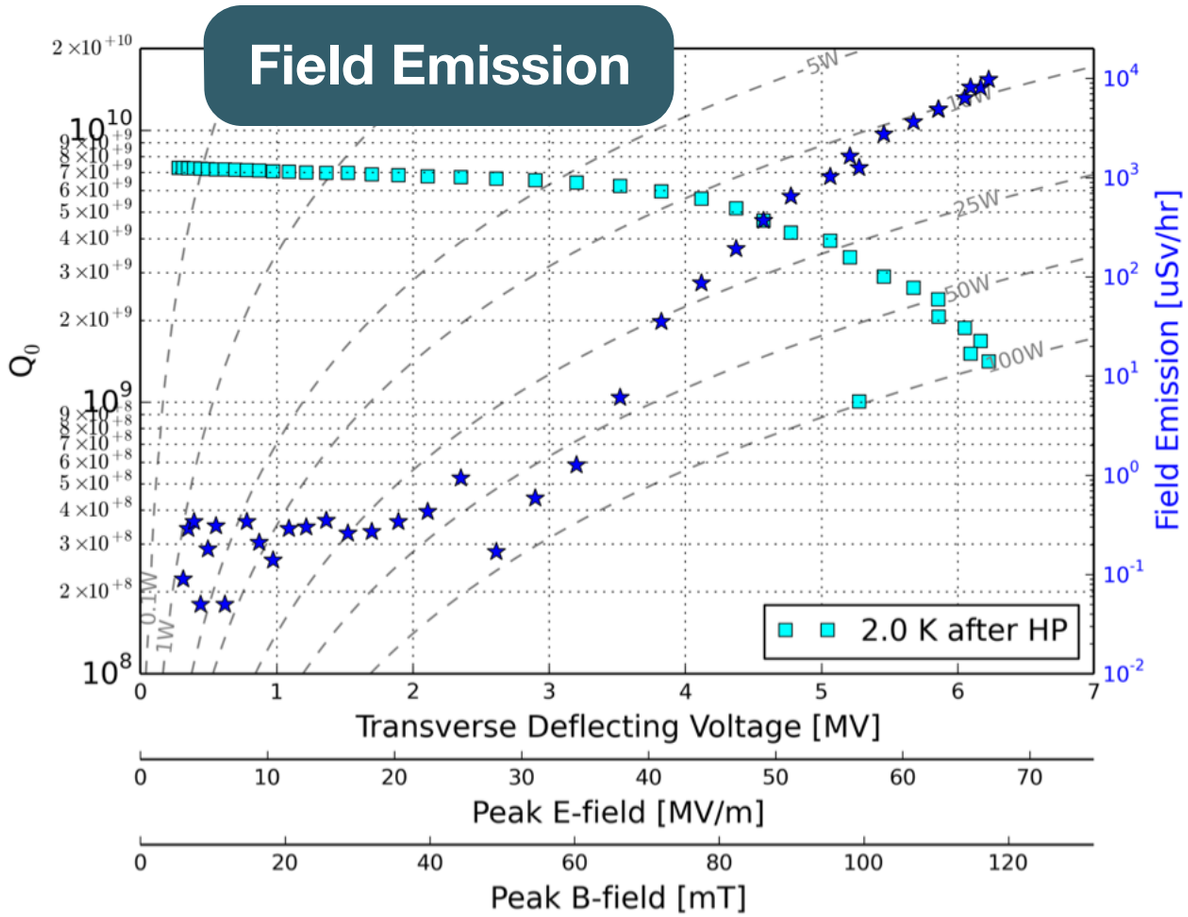


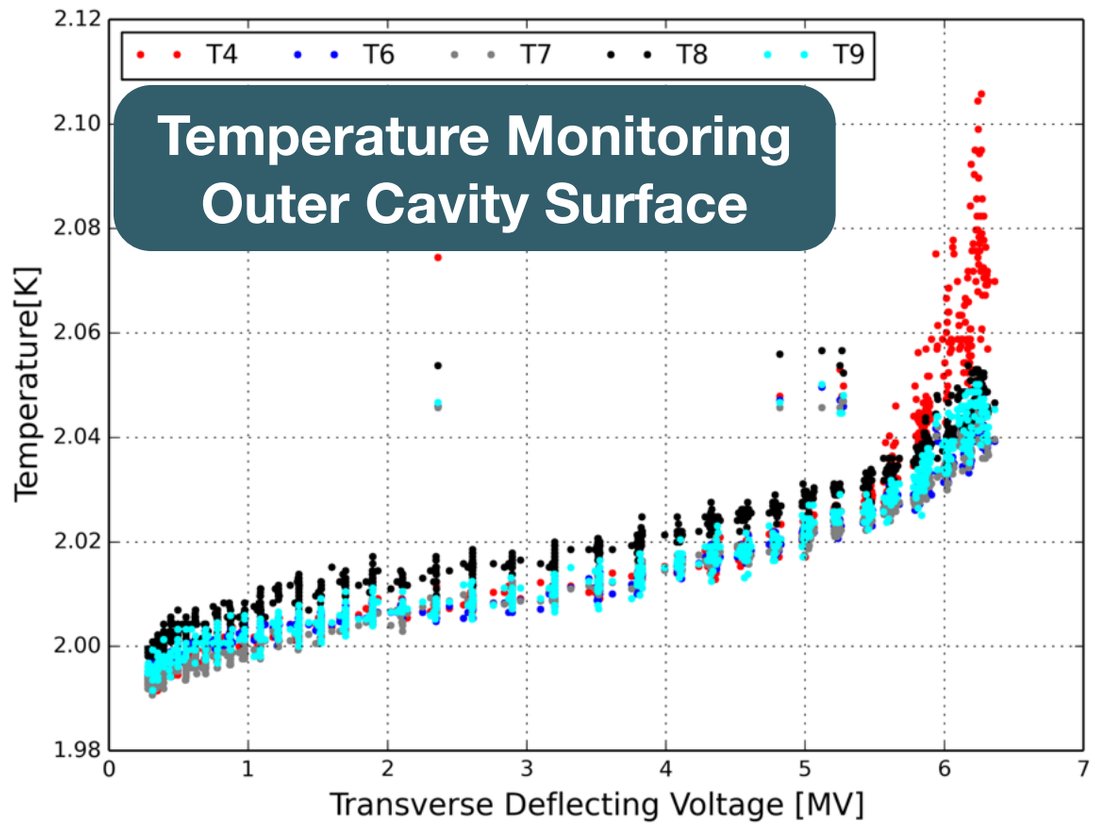




- **Clear spatial temperature gradient**
- **2 different cooling rates tried**
  - No performance difference
  - Not yet a systematic study …
- **Flux expulsion at level of ~200nT**

RFD: Temperature Monitoring





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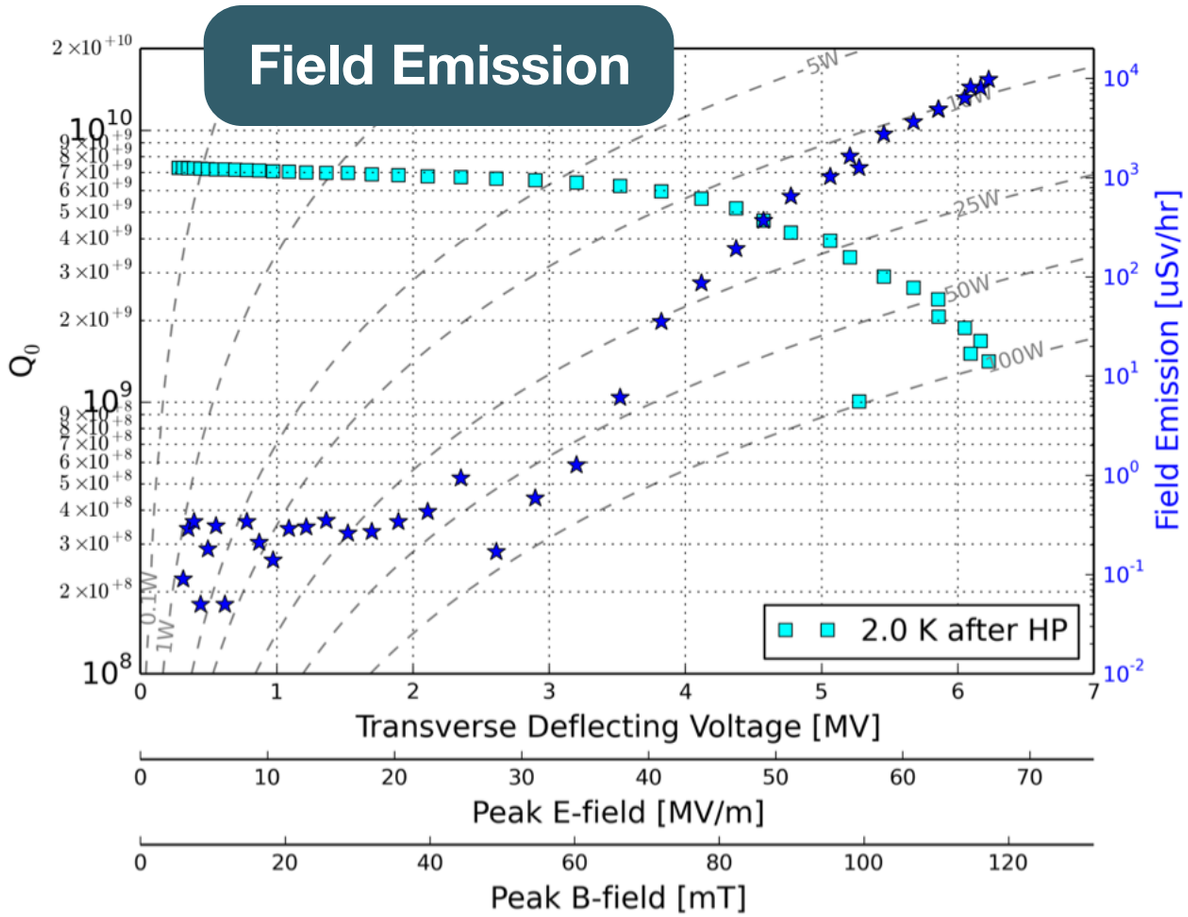
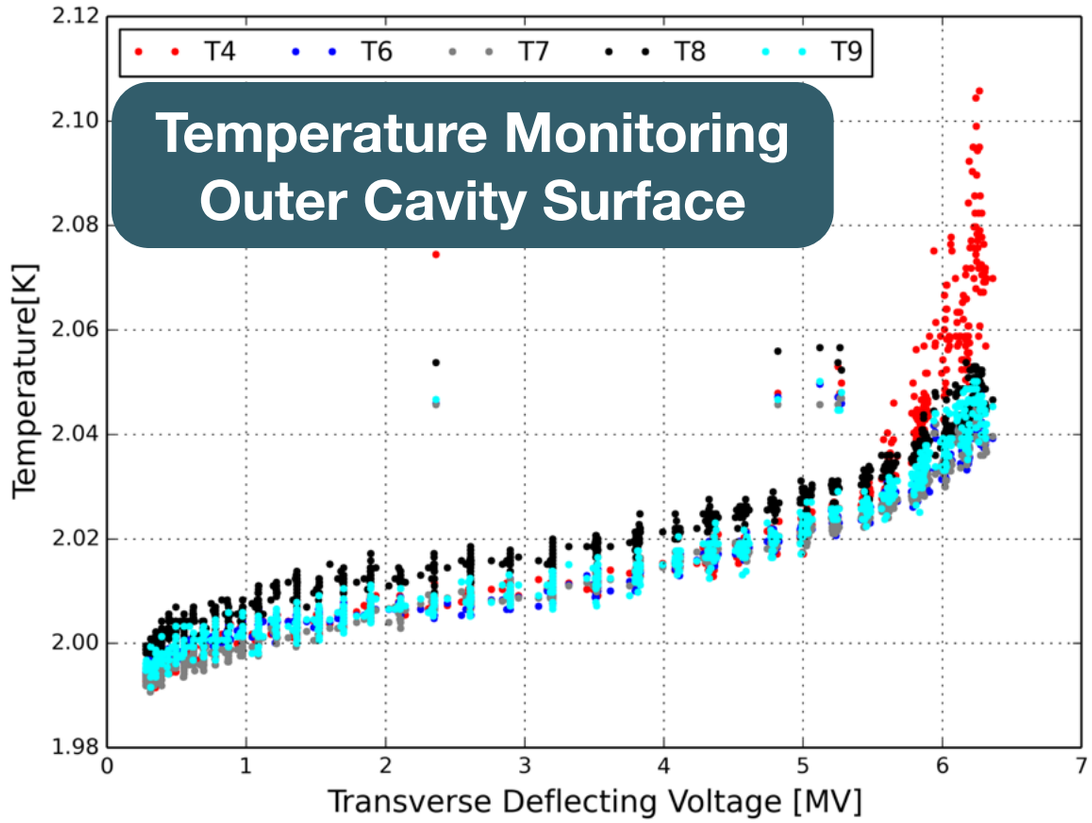
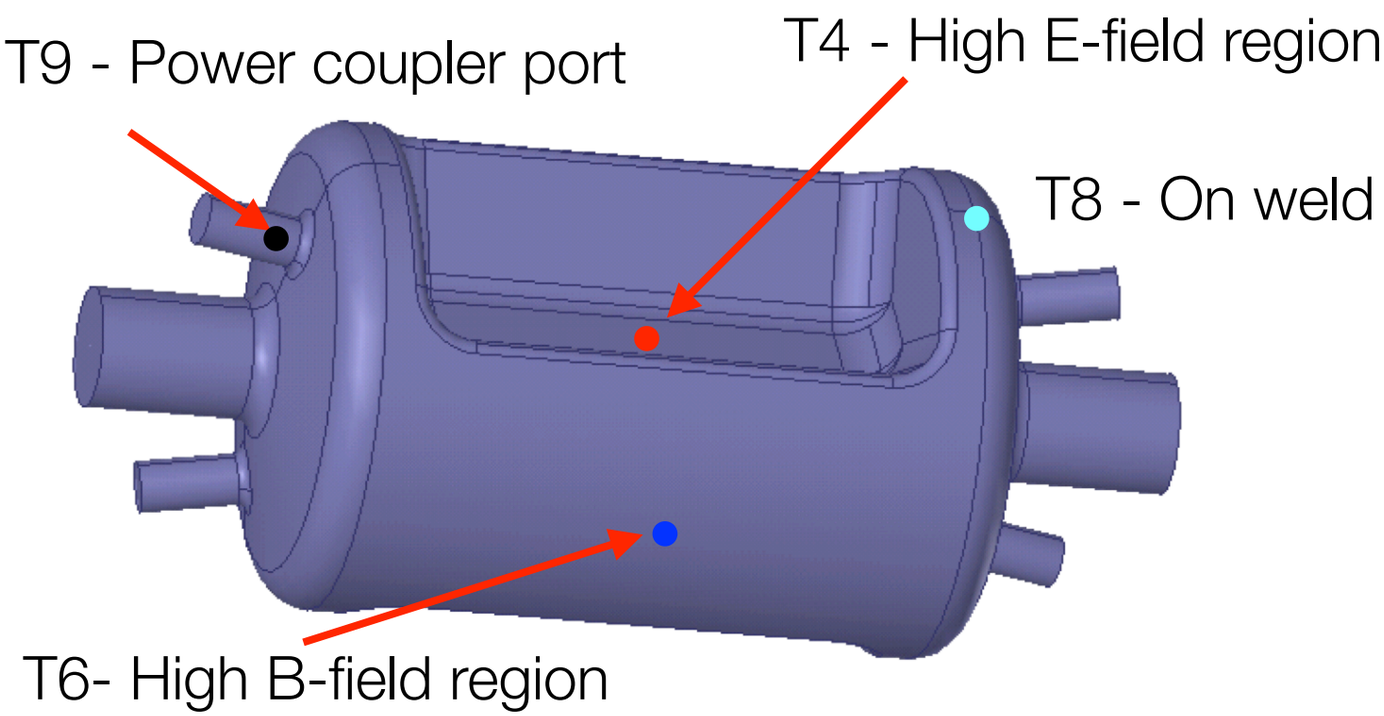
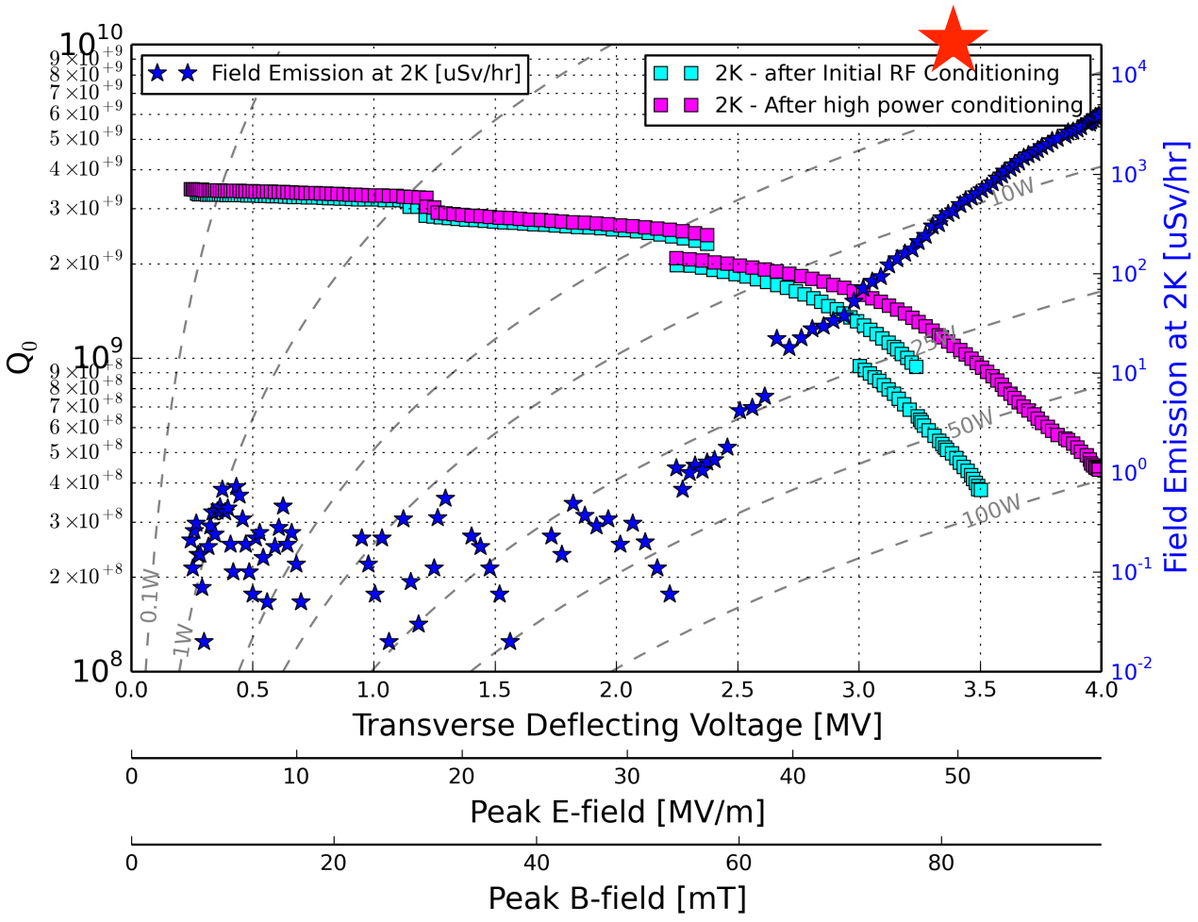


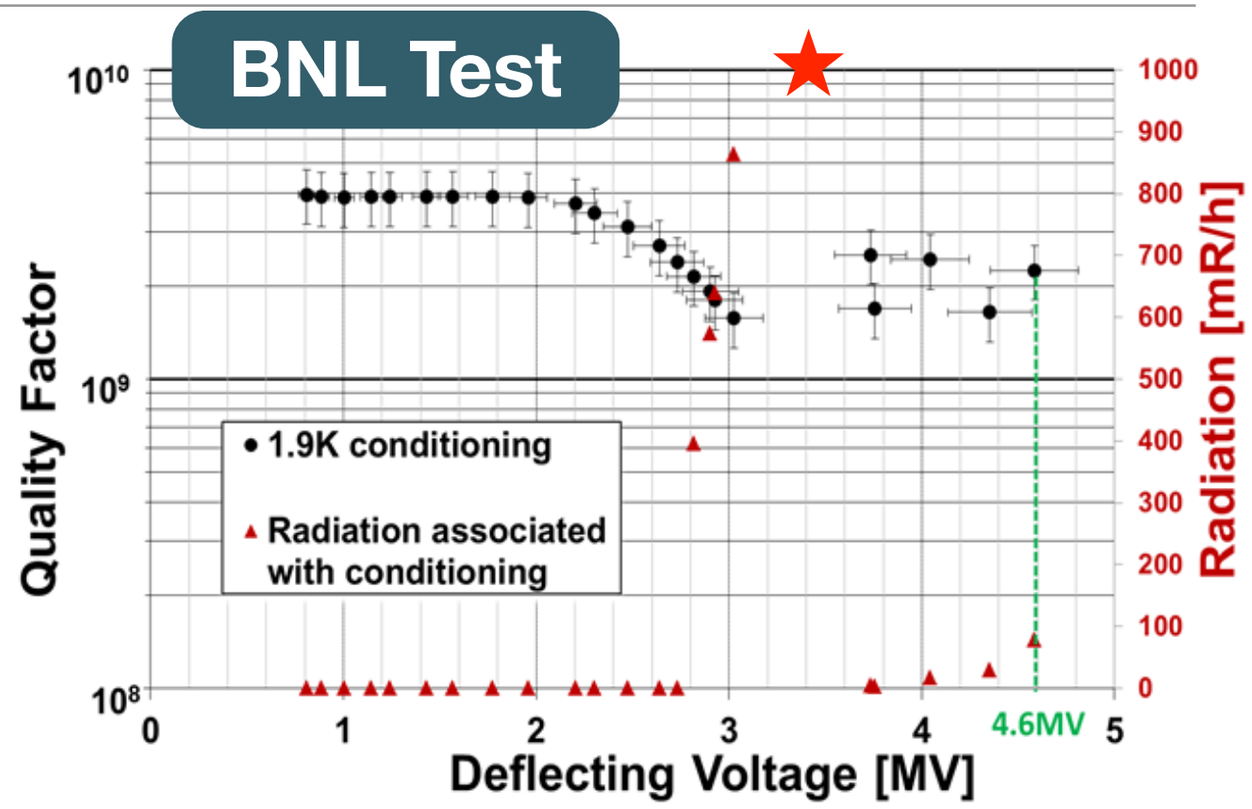




- **Field emission at above 3MV**
  - => induces collapse of fields
- **Heating observed on cavity**
  - appeared in High E-field region
  - measured on outer surface

DQW: Comparison of results with BNL





- **Please note:**
  - **Cold test is still ongoing**
  - **Cavity conditioning still ongoing**
  - Helium processing not yet done

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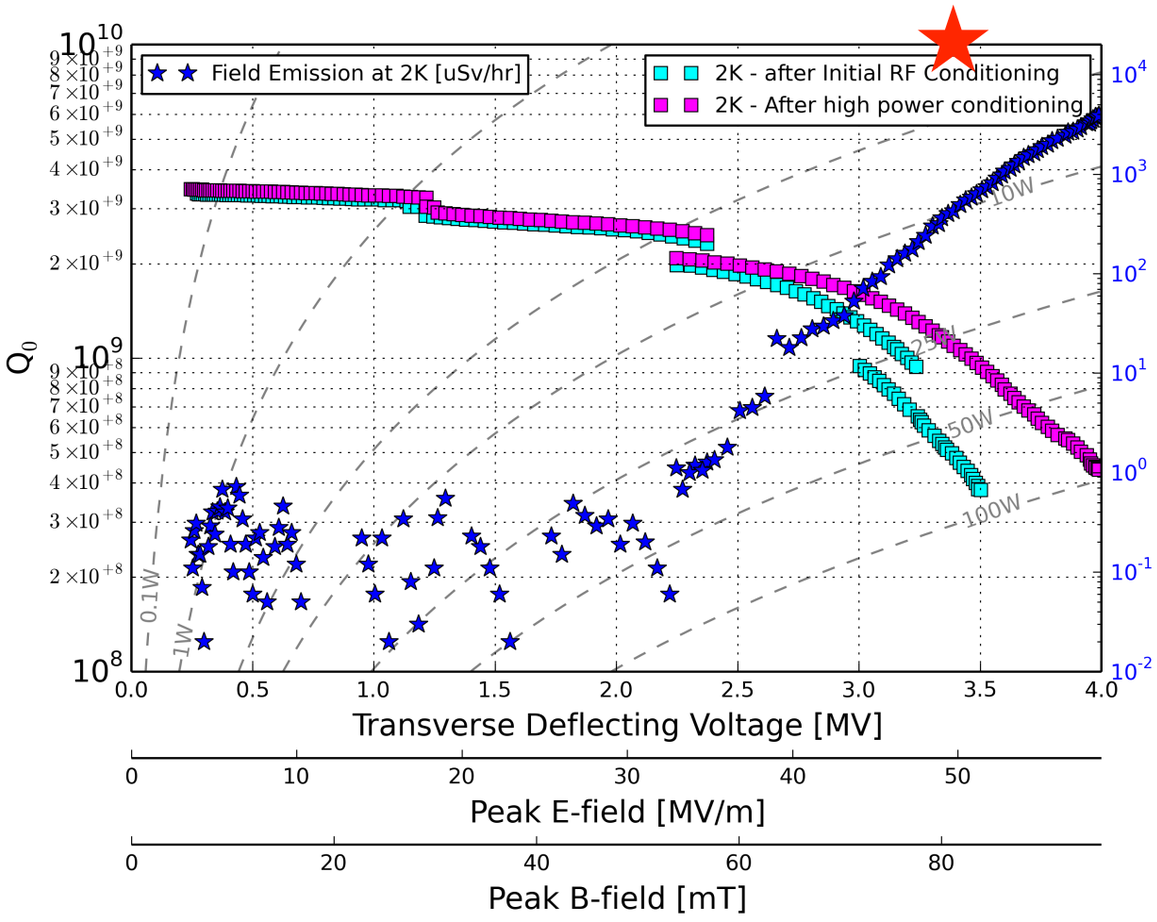

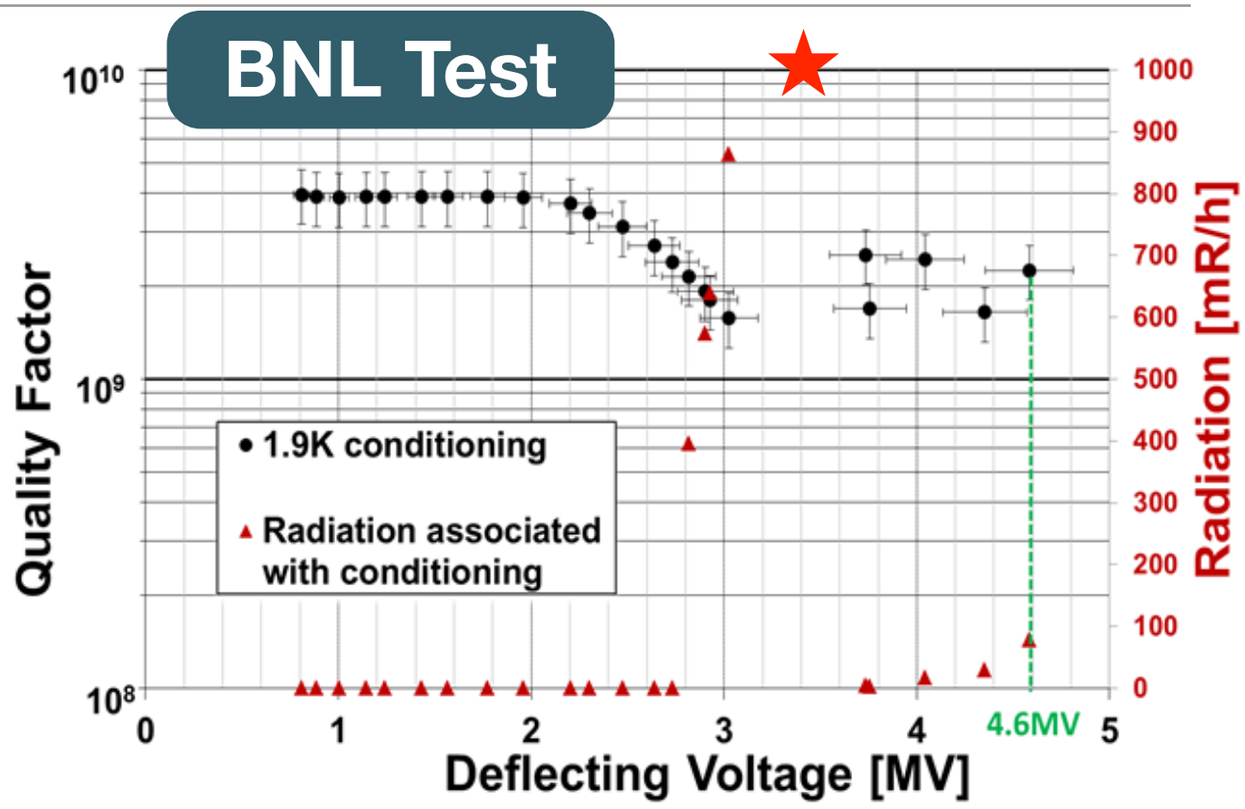

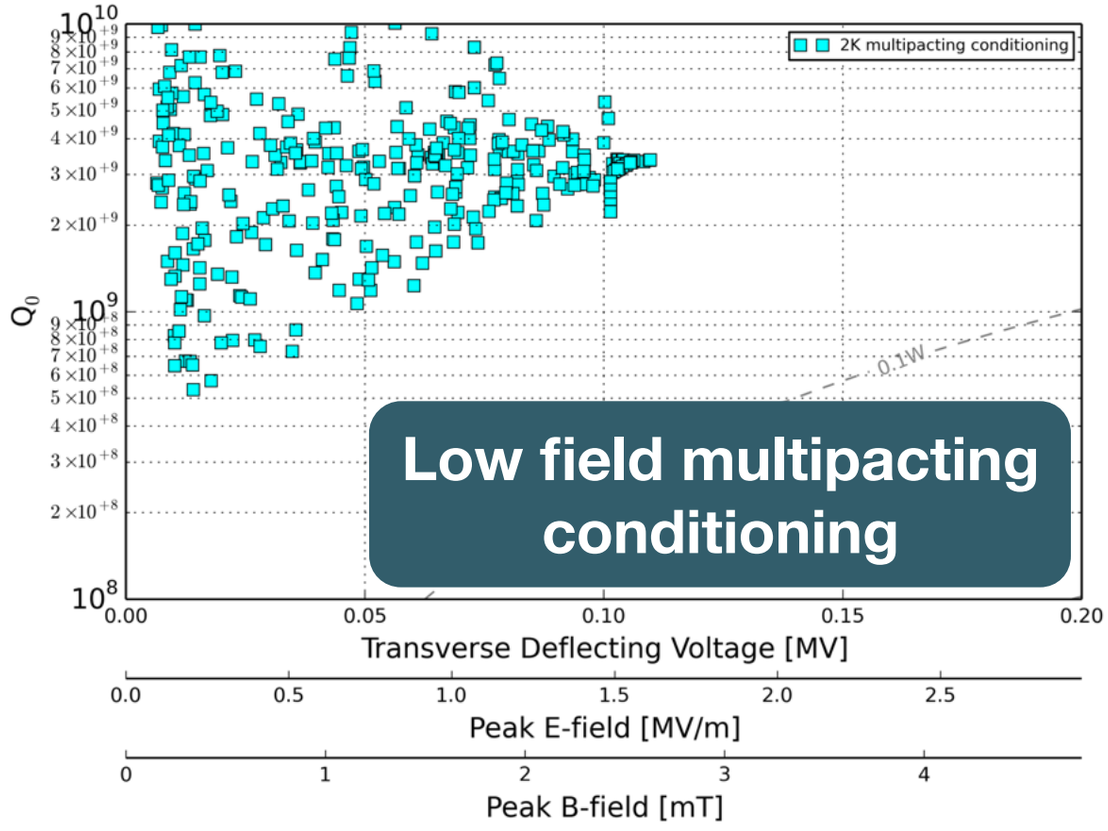

- **Please note:**
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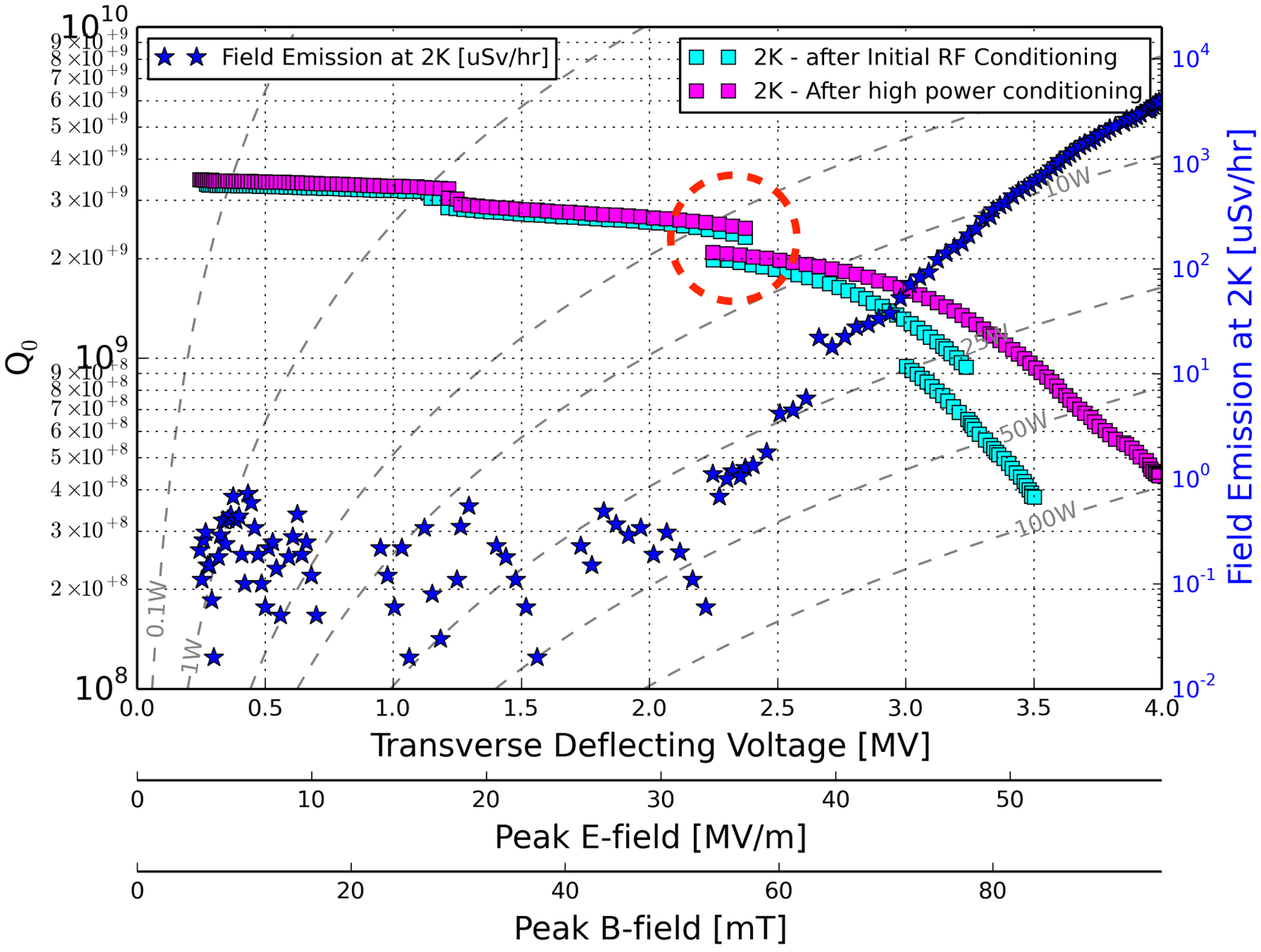
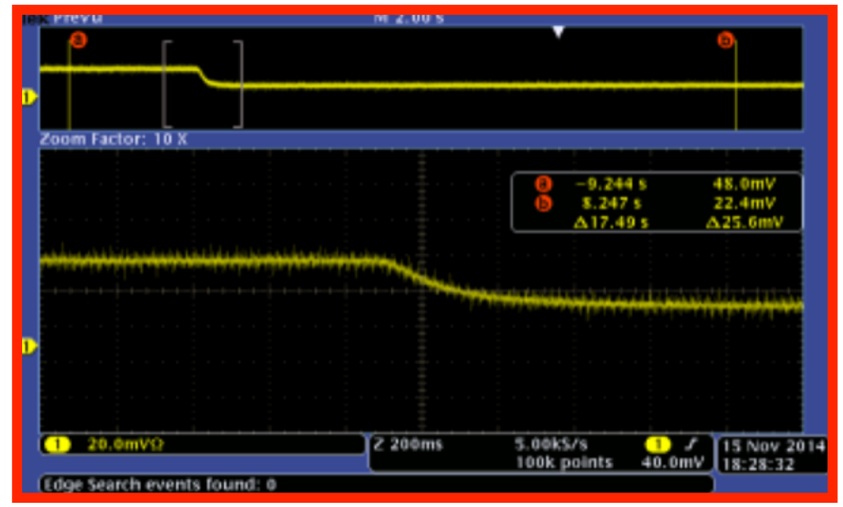
  - **Cavity conditioning still ongoing**
  - Helium processing not yet done

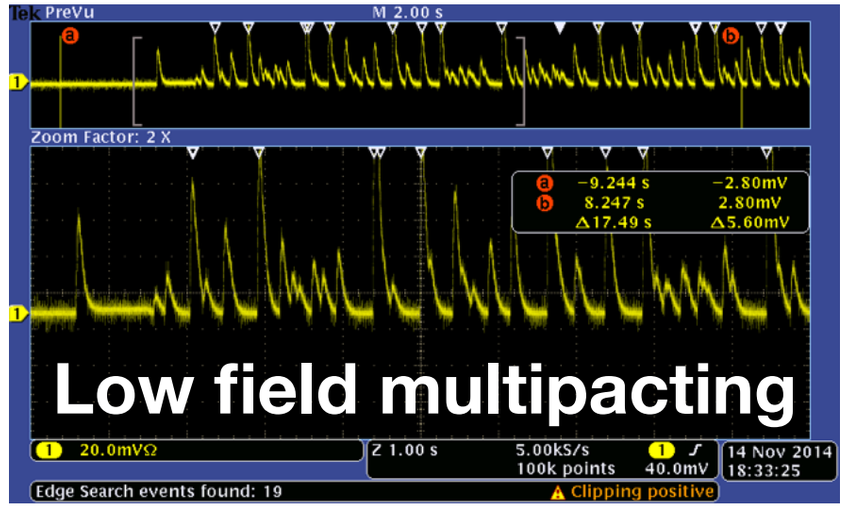
DQW: SM18 Cold test results

- **Low field Multipacting conditioned away**
- **Higher field discharges observed**
- **Residual resistance ~ 23.5 nΩ (18.3 nΩ at BNL)**
- **Low Field Q_0 = 3.45 x 10^9**

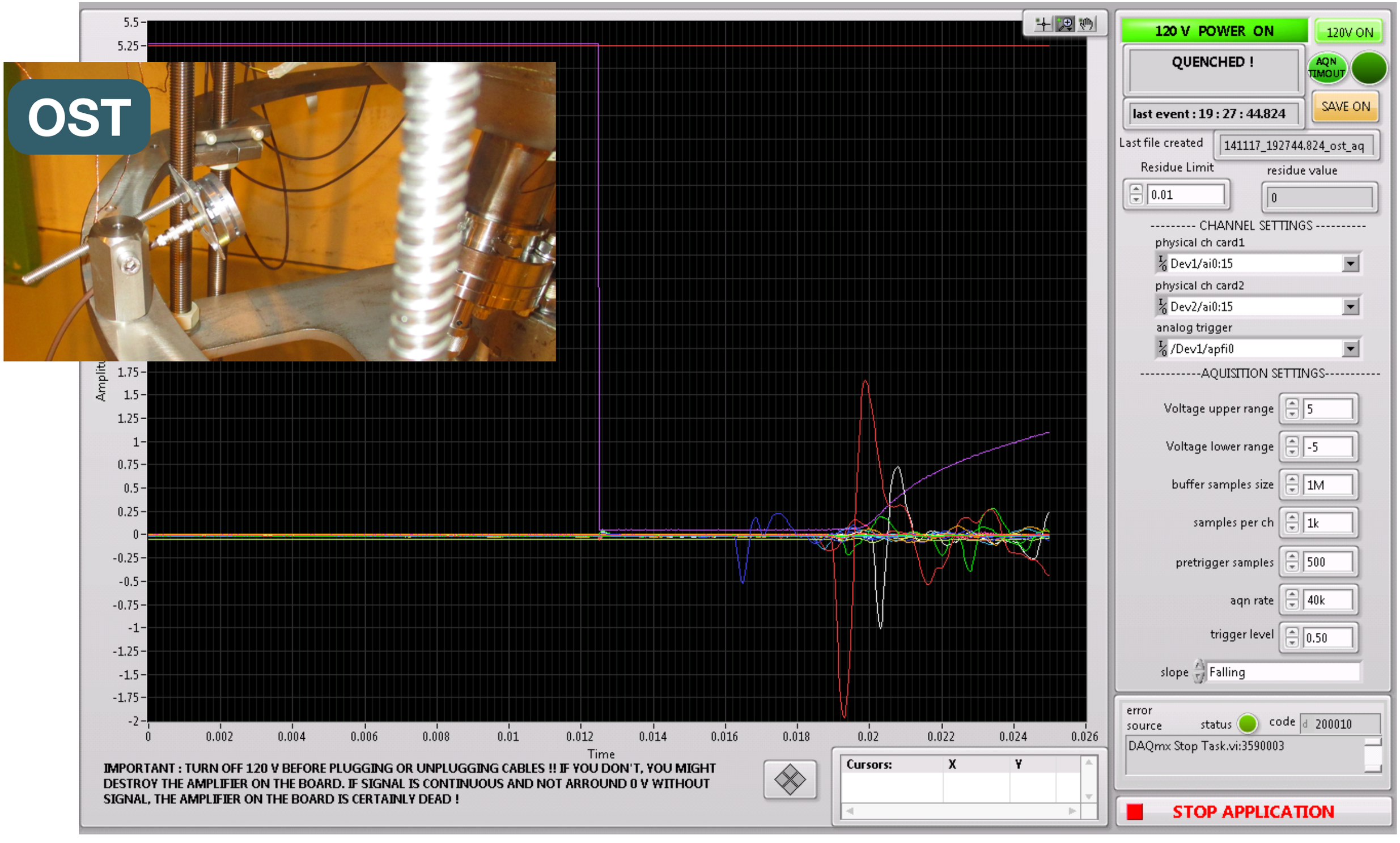




DC current monitor on pickup antenna



DQW: Quench monitoring from 2nd Sound



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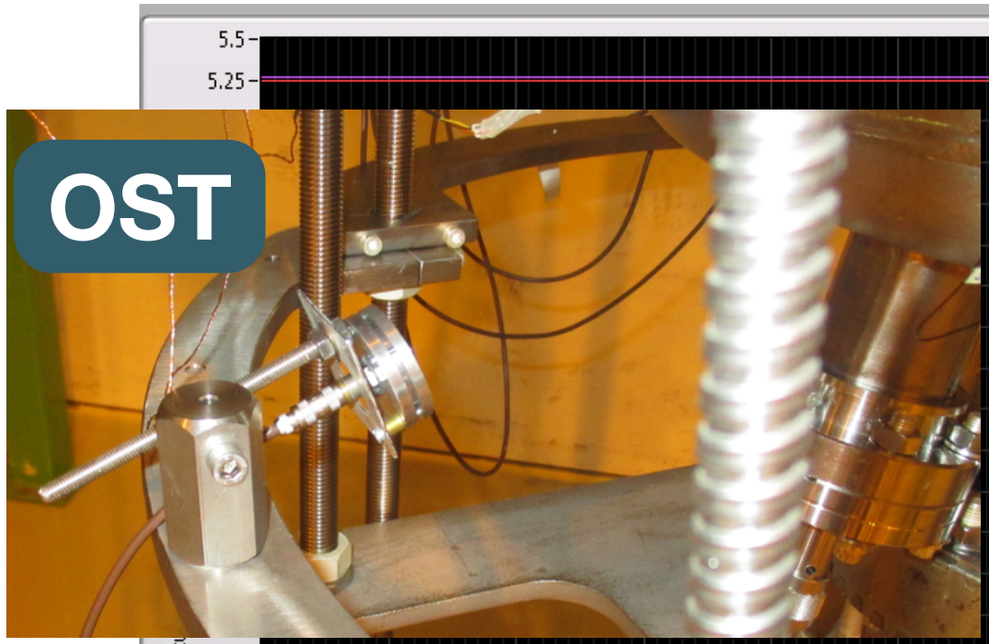
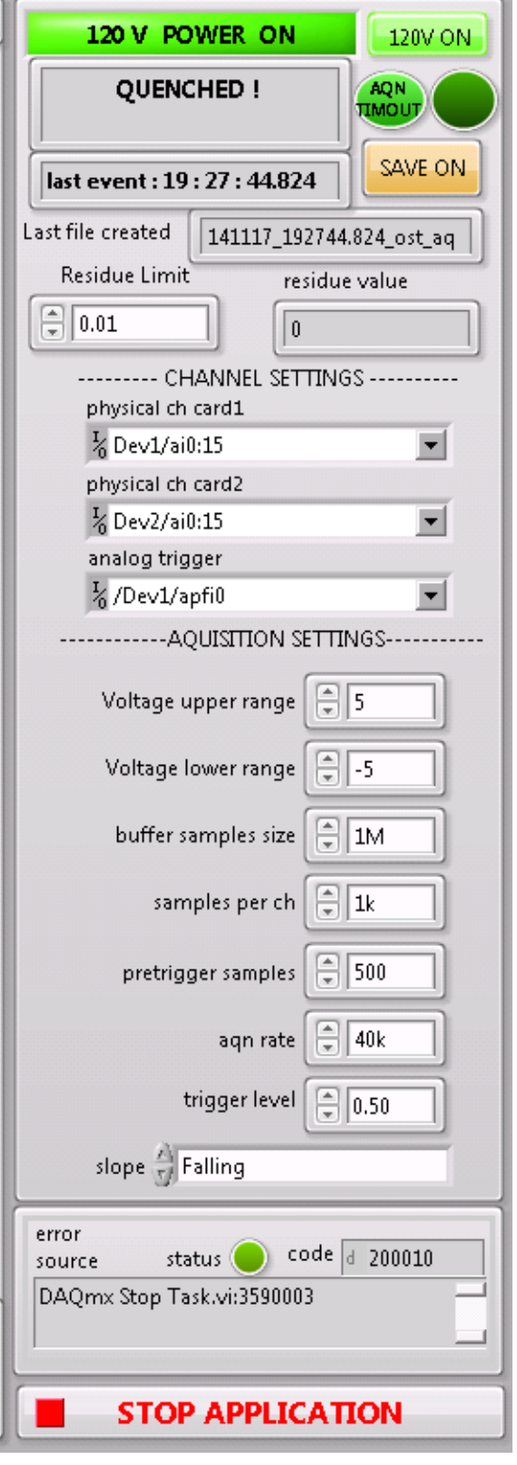
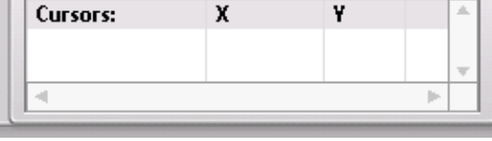


Quench location:
near FPC port



IMPORTANT : TURN OFF 120 V BEFORE PLUGGING OR UNPLUGGING CABLES !! IF YOU DON'T, YOU MIGHT DESTROY THE AMPLIFIER ON THE BOARD. IF SIGNAL IS CONTINUOUS AND NOT ARROUND 0 V WITHOUT SIGNAL, THE AMPLIFIER ON THE BOARD IS CERTAINLY DEAD !



Outlook into 2015

- **Continue with DQW tests until 28th November**
  - SM18 Cryo stop 17th December till End of February

- **Cryo shutdown: Need to upgrade cryostat inserts & test stand**
  - Prepare inserts for testing with mobile power coupler and cavity tuner
  - Upgrade large cryostat insert … possibility of 2 crabs in 1 cryostat
  - **Make operational a medium size cryostat specifically for crab testing**

- **Once cryo restarted March 2015: Cold test of PoP Cavities**
  - Cavity test with tuner + re-test & study PoP Cavities
  - Quench studies and input measurements for LLRF design

- **2015: Follow layout + tooling preparation for SM18 M7 Horizontal bunker**
  - Includes both clean room and bunker preparations