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| Traveler Title | LCLSII (Production Cryomodule) Vertical cavity Testing |
| Traveler Abstract | Cryogenic RF testing of 1300MHz 9-cell cavities for LCLSII Producion Cryomodules |
| Traveler ID | L2PRD-CAV-VTRF |
| Traveler Revision  | R3 |
| Traveler Author | Kirk Davis |
| Traveler Date | 17-Aug-2016 |
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| Approval Names | K. Davis | A. Palczewski | A. Reilly | K. Wilson |
| Approval Signatures |  |  |  |  |
| Approval Dates |  |  |  |  |
| Approval Title | Author, VTA Manager | Reviewer | Project Manager | Cavity SOTR |

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| References | List and Hyperlink all documents related to this traveler. This includes, but is not limited to: safety (THAs, SOPs, etc), drawings, procedures, and facility related documents. |
| [VTA SOP](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-27461/A-09-001-SOP%20Operation%20of%20the%20Test%20Lab%20VTA%20Document-21542.pdf) | **LCLSII VTA RF Testing Procedure** | [**Excel spreadsheet template for VTA RF measurements**](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-98189/SpreadsheetTemplate%20for%20STP-CAV-VTRF_12Nov2014.xlsm) | [9-Cell Quench Analysis](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-148149/L2_xyzModeAnalysismm_dd_yyyy.xlsx) |  |
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| Revision Note |  |
| R1 | Initial release of this Traveler. |
| R2 | Change acceptance criteria per recent LCLSII project guidance, change radiation limits |
| R3 | Added FEFree fields. Changed limits and specifications in steps 13, 14, 17. Added step 0 |

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| **Step No.** | **Instructions** | **Data Input** |
| 0 | Was cavity kept under vacuum since it was shipped from the vendor? | [[CavVacuum]] <<YESNO>> |
| 1 | Input LCLSII 9-cell cavity ID, Epk/Eacc, and Bpk/EaccNote any special handling, processing (chemistry or bake) or off-normal conditions associated with this cavity before test. | [[CAVSN]] <<CAVSN>>[[EpkEaccRatio]]<<FLOAT>>[[Default1\_99]]<<COMMENT>>[[BpkEaccRatio]]<<FLOAT>>[[Default4\_26]]<<COMMENT>>[[Special\_handling]] <<COMMENT>> |
| 2 | Record if cavity has SS or NbTi flanges | [[FlangeType]]{{SS,NbTi}}<<SELECT>> |

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| 3 | Enter the LabView file name, without special characters. (Valid example: CAV\_0045). | [[LabviewFile]] <<TEXT>> |
| 4 | Record Test Date, Dewar No, Top Plate ID and Operator(s). | [[TestDate]] <<TIMESTAMP>>[[Dewar]] {{8,7,5,4,3}} <<SELECT>>[[VTATSSN]] <<VTATSSN>>[[TestOperator1]] <<VTAOPS>>[[TestOperator2]] <<VTAOPS>> |
| 5 | Record cavity vacuum pressure, if so instrumented. If at 2.0K cavity vacuum is greater than 5x10-6 mbar chose option No in CavityVacuumOK, record pertinent information , abort RF power test and launch NCR. | [[CavityVacuum]] <<SCINOT>>[[VacuumUnits]] {{(mbar),( Torr),(Pa)}} <<SELECT>>[[CavityVacuumOK]] <<YESNO>>[[CavityVacuumComment]] <<COMMENT>> |
| 6 | Record dewar helium liquid level, temperature and pressure. Do not continue unless Dewar LHe level is above the end group. Start cavity testing at 23(+/-0.1) Torr (2.0K); level >181cm. | [[DewarLHeLevelcm]] <<FLOAT>>(cm)[[DewarTempK]] <<FLOAT>>(K)[[DewarPressureTorrInitial]] <<FLOAT>>(Torr) |

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| 7 | Per the **LCLSII VTA RF Testing Procedure**, perform low power measurements using a network analyzer (measure the nine cavity mode frequencies). Record the cavity mode frequencies at the right. Example of cavity mode frequencies: |
| 9\_9Pi = 1300.250 MHz | [[Freq\_9\_9Pi]] <<FLOAT>>(MHz) |
| 8\_9Pi = 1299.448 MHz | [[Freq\_8\_9Pi]] <<FLOAT>>(MHz) |
| 7\_9Pi = 1297.121 MHz | [[Freq\_7\_9Pi]] <<FLOAT>>(MHz)  |
| 6\_9Pi = 1293.613 MHz | [[Freq\_6\_9Pi]] <<FLOAT>>(MHz)  |
| 5\_9Pi = 1289.376 MHz | [[Freq\_5\_9Pi]] <<FLOAT>>(MHz)  |
| 4\_9Pi = 1284.892 MHz | [[Freq\_4\_9Pi]] <<FLOAT>>(MHz)  |
| 3\_9Pi = 1280.721 MHz | [[Freq\_3\_9Pi]] <<FLOAT>>(MHz)  |
| 2\_9Pi = 1277.307 MHz | [[Freq\_2\_9Pi]] <<FLOAT>>(MHz)  |
| 1\_9Pi = 1275.087 MHz | [[Freq\_1\_9Pi]]<<FLOAT>>(MHz) |
| 8 | At 2.0 K determine and record Dewar pressure (baratron) and cavity Pi-mode lock frequency precisely with LLRF frequency counter – per the **LCLSII VTA RF Testing Procedure**. **Lock frequency specifications:** * **Low: 1300.150MHz**
* **High: 1300.350MHz**

If option NO is checked, launch NCR**.** | [[LockFrequency]] <<FLOAT>>(MHz)[[DewarPressureTorr]] <<FLOAT>>(Torr) |
| 9 | At cavity field of 3-5MV/m, determine cavity coupling per the **LCLSII VTA RF Testing Procedure**. Upload Tektronics oscilloscope screen (TDS\_.txt) data file. | [[CavityCoupling]] {{Overcoupled,Undercoupled}} <<SELECT>>[[TDS\_txt]] <<FILEUPLOAD>> |

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| 10 | Perform decay measurements and record Eacc, Qo, Qext2, Qext1, %error, radiation, QextHOMa**,**  QextHOMb**.** and Decay Time chosen for CW high power tests as specified in **LCLSII VTA RF Testing Procedure**. Typical values during decay measurements for:  |
| Eacc : (4+/-1) MV/m | [[Eacc]] <<FLOAT>> (MV/m)  |
| Qo : ~2.2 e10 | [[Qo]]<<SCINOT>> |
| Qext1 : 1.1-1.9 e10 | [[Qextin]]<<SCINOT>> |
| **Qext2 : 2.5-7.0 e11** (launch NCR if not in range) | [[Qextfp]]<<SCINOT>> |
| %error : 8-13 | [[Qextfperror]]<<FLOAT>> (%) |
| Radiation : 1 e-3 mR/hr | [[Rad]]<<SCINOT>> (mR/hr)  |
| **QextHOMa : >= 2.7e11** (launch NCR if not in range) | [[QextHOMa]]<<SCINOT>> |
| **QextHOMb : >=2.7e11** (launch NCR if not in range) | [[QextHOMb]]<<SCINOT>> |
| Decay Constant: ~1 second | [[Tau]] <<FLOAT>> (seconds) |

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| 11 | At 2.0K and in 9/9 Pi mode, test the cavity performance up to its’ maximum operating gradient observing the administrative limits as specified in **LCLSII VTA RF Testing Procedure**. Increment ~0.5 MV from 1 MV to <= 18 MV/m; <= 1 quench. |
| 12 | InitialFEonset: onset of field emission (FE onset, defined to be the first measured gradient where sustained radiation is >= 3e-2 mR/hr). If FE onset occurs below 10MV/m, abort the test. If no field emission is detected up to administrative limit (18 MV/m) insert a value of Emax. Transient radiation due to multipacting should not be recorded here. DO NOT EXCEED 1R/hr without PI approval. | [[Init\_FEonsetMVm]] <<FLOAT>>(MV/m)[[Init\_FEFree]] <<CHECKBOX>> |
| 13 | **Initial Qo at (16+/-0.1) MV/m**. Acceptance criteria Qo >= 2.5e10 with SS input coupler flange. (launch NCR if not in range) | [[init\_QoAt16MVm]]<<SCINOT>>(MV/m)  |
| Initial value for Radiation at 16 MV/m. | [[Init\_RadAt16MVm]] <<SCINOT>>(mR/h)  |
| Initial power rise maximum cavity gradient achieved Emax. limit 19.5 MV/m | [[init\_EmaxMVm]] <<FLOAT>>(MV/m) |
| Qo value at maximum cavity gradient. | [[init\_QoAtEmax]] <<SCINOT>> |
| Initial Rmax value for the highest radiation level inside Dewar lid. If Rmax is background up to the administrative limit (18MV/m), insert 1e-3 mR/m for this parameter. | [[init\_Radmax]] <<SCINOT>>(mR/h) |
| Record performance limitation at 2.0K.If cavity PerformanceLimitAt2\_0K is selected Other, record pertinent information in the Comment box at the right. | [[PerformanceLimitAt2\_0K]] {{Admin,RF power,FE,Quench(non FE),Cable,Operator,Other}} <<SELECT>>[[PerformLimitAt2\_0K\_Other]] <<COMMENT>> |
| Record Lorentz detuning coefficient (slope of the linear fit frequency vs Eacc2) KLoren.**Lorentz detuning coefficient specifications:** * **Low: -0.6**
* **High: -1.2 Hz/(MV/m)^2**

If option NO is checked, launch NCR. | [[KLOREN]] <<FLOAT>>(Hz/MVm2)[[KLORENComment]] <<COMMENT>> |

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| 14 | Perform 1.8K QvsE observing the administrative limits as specified in **LCLSII VTA RF Testing Procedure**. <= 19.5 MV/m (1MV/m steps from 1MV to admin limit) |
| 15 | Perform decay measurements and record Eacc, Qo, Qext2, Qext1, %error, radiation, QextHOMa**,**  QextHOMb**.** and Decay Time chosen for CW high power tests as specified in **LCLSII VTA RF Testing Procedure**. Typical values during decay measurements for:  |
| Eacc : (4+/-1) MV/m | [[Eacc2]] <<FLOAT>> (MV/m)  |
| Qo : ~3.5 e10 | [[Qo2]]<<SCINOT>> |
| Qext1 : 1.1-1.9 e10 | [[Qextin2]]<<SCINOT>> |
| **Qext2 : 2.5-7.0 e11** (launch NCR if not in range) | [[Qextfp2]]<<SCINOT>> |
| %error : 8-13 | [[Qextfperror2]]<<FLOAT>> (%) |
| Radiation : 1 e-3 mR/hr | [[Rad2]]<<SCINOT>> (mR/hr)  |
| **QextHOMa : >= 2.7e11** (launch NCR if not in range) | [[QextHOMa2]]<<SCINOT>> |
| **QextHOMb : >= 2.7e11** (launch NCR if not in range) | [[QextHOMb2]]<<SCINOT>> |
| Decay Constant: ~1 second | [[Tau2]] <<FLOAT>> (seconds) |
| 16 | Perform 1.6K QvsE observing the administrative limits as specified in **LCLSII VTA RF Testing Procedure**. <= 19.5 MV/m (1MV/m steps from 1MV to admin limit) |
| 17 | Perform decay measurements and record Eacc, Qo, Qext2, Qext1, %error, radiation, QextHOMa**,**  QextHOMb**.** and Decay Time chosen for CW high power tests as specified in **LCLSII VTA RF Testing Procedure**. Typical values during decay measurements for:  |
| Eacc : (4+/-1) MV/m | [[Eacc3]] <<FLOAT>> (MV/m)  |
| Qo : ~5.6 e10 | [[Qo3]]<<SCINOT>> |
| Qext1 : 1.1-1.9 e10 | [[Qextin3]]<<SCINOT>> |
| **Qext2 : 2.5-7.0 e11** (launch NCR if not in range) | [[Qextfp3]]<<SCINOT>> |
| %error : 8-13 | [[Qextfperror3]]<<FLOAT>> (%) |
| Radiation : 1 e-3 mR/hr | [[Rad3]]<<SCINOT>> (mR/hr)  |
| **QextHOMa : >= 2.7e11** (launch NCR if not in range) | [[QextHOMa3]]<<SCINOT>> |
| **QextHOMb : >=2.7e11** (launch NCR if not in range) | [[QextHOMb3]]<<SCINOT>> |
| Decay Constant: ~1 second | [[Tau3]] <<FLOAT>> (seconds) |
| 18 | 2.0K Push the cavity to its operating limit observing the administrative limits as specified in **LCLSII VTA RF Testing Procedure**. <= 24 MV/m (1.0 MV increments). DO NOT EXCEED 1R/hr without PI approval. |
| 19 | If the cavity does not meet the acceptance criteria (16 MV/m, >= 2.5e10 for SS flanges) due to quench and/or FE loading, contact the PI (or their designee) before performing this step.At 2.0K, keeping the same Qextfp as used for the π mode, attempt to find the related unscaled Quench fields for each member of the fundamental passband. Use caution since HOM filters can pass excessive power at frequencies lower than π-mode (8/9, 7/9, …). | [[EaccUnscaledQuench\_9\_9Pi]] <<FLOAT>>(MV/m)[[EaccUnscaledQuench\_8\_9Pi]] <<FLOAT>>(MV/m)[[EaccUnscaledQuench\_7\_9Pi]] <<FLOAT>>(MV/m) [[QuenchStudyComment]]<<COMMENT>> |

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| 20 | 2.0K final “clean” QvsE (1MV/m steps from 1MV to limit). “Clean” curve should have no new FE processing or FE activation. Repeat power rise until QvsE and FEvsE become static and reproducable. DO NOT EXCEED 1R/hr without PI approval. |
| At (4.0 +/-0.3) MV/m, record Eacc and Q0 | [[Eacc\_Grad\_4]] <<FLOAT>>(MV/m)[[Qo\_Grad\_4]]<<SCINOT>> |
| At (16.0 +/-0.3) MV/m, record Eacc and Q0 | [[Eacc\_Grad\_16]] <<FLOAT>>(MV/m)[[Qo\_Grad\_16]]<<SCINOT>> |
| At (19.0 +/-0.3) MV/m, record Eacc and Q0 | [[Eacc\_Grad\_19]] <<FLOAT>>(MV/m)[[Qo\_Grad\_19]]<<SCINOT>> |
| Performance note: record information about cavity performance, limitations and other pertinent observations. **Emax >= 19 MV/m, FE onset > 17.5 MV/m**  (launch NCR if not in range). | [[CavityPerformance]] <<COMMENT>>[[final\_EaccFEOnset]]<<FLOAT>>(MV/m)[[final\_FEFree]] <<CHECKBOX>>[[final\_EmaxMVm]] <<FLOAT>>(MV/m)[[final\_QoAtEmax]] <<SCINOT>>[[final\_Radmax]] <<SCINOT>>(mR/h) |

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| 21 | Process and upload the VTA RF testing results, using the [Excel file template](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-27853/Excel%20spreadsheet%20template%20for%20C100-CAV-VTRF.xlsx). |
| 22 | Upload the raw data file with VTA RF testing results using file name: CavID raw data.txt. | [[RF\_test\_raw\_data]] <<FILEUPLOAD>> |
| 23 | Upload processed (Excel) data file results using file name: CavID processed data.xlsx | [[RF\_test\_processed]] <<FILEUPLOAD>> |
| 24 | Upload processed Qo-and-Rad -vs-Eacc graph (in PDF format) using file name: QoandRadvsEacc.pdf Upload processed HOMa and HOMb vs Eacc graph (in PDF format) using file name: CavID\_HOMaHOMbvsEacc.pdfUpload processed f-vs-Eacc2 graph (in PDF format) using file name: CavID\_FreqvsEacc2.pdfAbove for initial and final power rise (2.0K) | [[UploadFiles1]] <<FILEUPLOAD>> |
| 25 | Upload any additional processed data files collected during this test, in the test using file name: CavID\_OTHER.pdf or any other file name properly describing the CavID and the graph content. | [[UploadFiles2]] <<FILEUPLOAD>> |
| 26 | **Cavity passed all specifications for this traveler: 11, 13, 16 and 21?** If NO option is chosen ensure that appropriate NCR(s) have been issued from this traveler. | [[CavityMeetsSpecifications]] <<YESNO>> |
| 27 | Verify all steps have been completed and all data has been entered. | [[VerifyTraveler]] {{marhause,ari,kdavis,stirbet,edaly,areilly}} <<HOLDPOINT>> |