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| Traveler Title | LCLS-II HE Vertical Cavity Testing | | | |
| Traveler Abstract | Cryogenic RF testing of 1300MHz 9-cell cavities for LCLS-II-HE Producion Cryomodules | | | |
| Traveler ID | L2HE-CAV- VTRF | | | |
| Traveler Revision | R1 | | | |
| Traveler Author | Kirk Davis | | | |
| Traveler Date | 31-Mar-21 | | | |
| NCR Informative Emails | areilly,kwilson,hogan | | | |
| NCR Dispositioners | Kdavis,Ari | | | |
| D3 Emails | Kdavis,areilly,Ari,kwilson,hogan | | | |
| Approval Names | K. Davis | A. Palczewski | J. Hogan |  |
| Approval Signatures |  |  |  |  |
| Approval Dates |  |  |  |  |
| Approval Title | Author | Reviewer | Project Manager |  |

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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. | | | |
| Cavity Drawing Package F10023864\_rev\_M | [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](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-241341/CP-L2HE-VTA-CAV-VTRF-R1.docx) | [**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. |

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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 LCLS-II HE 9-cell cavity ID, Epk/Eacc, and Bpk/Eacc  Note any special handling, processing (chemistry or bake) or off-normal conditions associated with this cavity before test. | [[CAVSN]] <<CAVSN>>  [[EpkEaccRatio]]<<FLOAT>>  [[BpkEaccRatio]]<<FLOAT>>  [[Special\_handling]] <<COMMENT>> |

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| **Step No.** | **Instructions** | **Data Input** |
| 2 | Enter the LabView file name, without special characters. (Valid example: CAV\_0045). | [[LabviewFile]] <<TEXT>> |
| 3 | Record Test Date, Dewar No, Top Plate ID and Operator(s). | [[TestDate]] <<TIMESTAMP>>  [[Dewar]] {{5,7,8}} <<SELECT>>  [[VTATSSN]] <<VTATSSN>>  [[TestOperator1]] <<VTAOPS>>  [[TestOperator2]] <<VTAOPS>> |
| 4 | 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>> |
| 5 | 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 >171cm. | [[DewarLHeLevelcm]] <<FLOAT>>(cm)  [[DewarTempK]] <<FLOAT>>(K)  [[DewarPressureTorrInitial]] <<FLOAT>>(Torr) |

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| **Step No.** | **Instructions** | | | **Data Input** |
| 6 | 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) |
| 7 | 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 frequency is not within specifications, launch NCR.** | | | [[LockFrequency]] <<FLOAT>>(MHz)  [[DewarPressureTorr]] <<FLOAT>>(Torr) |
| 8 | At cavity field of 6-8 MV/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>> |
| 9 | | 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 : (7+/-1) MV/m | [[Eacc]] <<FLOAT>> (MV/m) | |
| Qo : ~2.2 e10 | [[Qo]] <<SCINOT>> | |
| Qext1 : 1.1-1.9 e10 | [[Qextin]] <<SCINOT>> | |
| **Qext2 : 0.75-2.5 e12** **(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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| **Step No.** | **Instructions** | **Data Input** |
| 10 | At 2.0K and in 9/9 Pi mode, test the cavity performance up to its maximum operating gradient per **LCLSII VTA RF Testing Procedure**. Increment ~0.5 MV from 2 MV to quench. | |
| 11 | 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. DO NOT EXCEED 1R/hr without PI approval. MP may be present from 18 to 24MV/m | [[Init\_FEonsetMVm]] <<FLOAT>> (MV/m)  [[Init\_FEFree]] <<CHECKBOX>>  [[MP\_Present]]<<CHECKBOX>> |
| 12 | **Initial Qo at (20.8+/-0.1) MV/m**. Acceptance criteria Qo >= 2.5e10 **(launch NCR if not in range)** | [[init\_QoAt21MVm]]<<SCINOT>> (MV/m) |
| Initial value for Radiation at 20.8 MV/m. | [[Init\_RadAt21MVm]] <<SCINOT>> (mR/h) |
| Power absorbed by HOMs at 20.8 MV/m. Acceptance criteria P\_HOM ≤ 1.7 W (launch NCR if not in range) | [[PHOMAat21MVm]] <<SCINOT>> (W)  [[PHOMBat21MVm]] <<SCINOT>> (W) |
| Initial power rise maximum cavity gradient achieved Emax. | [[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 Emax, insert 1e-3 mR/m for this parameter. | [[init\_Radmax]] <<SCINOT>> (mR/h) |
| Record performance limitation at 2.0K.  If cavity PerformanceLimitAt20K 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: -0.8** * **High: -1.2 Hz/(MV/m)^2**   If Lorentz force detuning coefficient not within specifications, launch NCR. | [[KLOREN]] <<FLOAT>> (Hz/MVm2)  [[KLORENComment]] <<COMMENT>> |

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| **Step No.** | **Instructions** | **Data Input** | |
| 13 | At 2.0 K and in 9/9 Pi mode, push the cavity to its operating limit per **LCLSII VTA RF Testing Procedure**. DO NOT EXCEED 1R/hr without PI approval. If MP is present from 17-24MV/m, MP processing must be performed for up to 1 hour. If MP remains contact the PI for guidance. | | |
| 14 | If the cavity does not meet the acceptance criteria (Emax >= 23 MV/m, Qo >= 2.5e10) 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>> | |
| 15 | 2.0K final “clean” QvsE (1MV/m steps from 1MV to limit). "Clean" curve should have no new FE processing, MP processing or FE activation. Repeat power rise until QvsE and FEvsE become static and reproduceable. 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 (20.8 +/-0.3) MV/m, record Eacc and Q0 | | [[Eacc\_Grad\_21]] <<FLOAT>> (MV/m)  [[Qo\_Grad\_21]]<<SCINOT>> |
| At (23.0 +/-0.3) MV/m, record Eacc and Q0 | | [[Eacc\_Grad\_23]] <<FLOAT>> (MV/m)  [[Qo\_Grad\_23]]<<SCINOT>> |
| Performance note: record information about cavity performance, limitations and other pertinent observations. Comment on multipacting, if applicable. **Emax >= 23 MV/m,** Qo@ 20.8MV/m>2.5e10 **(launch NCR if not in range).** | | [[CavityPerformance]] <<COMMENT>>  [[MultipactingComment]] <<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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| **Step No.** | **Instructions** | **Data Input** |
| 16 | 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). | |
| 17 | Upload the raw data file with VTA RF testing results using file name: CavID raw data.txt. | [[RF\_test\_raw\_data]] <<FILEUPLOAD>> |
| 18 | Upload processed (Excel) data file results using file name: CavID processed data.xlsx | [[RF\_test\_processed]] <<FILEUPLOAD>> |
| 19 | 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.pdf  Upload processed f-vs-Eacc2 graph (in PDF format) using file name: CavID\_FreqvsEacc2.pdf  Above for initial and final power rise (2.0K) | [[GraphUpload]] <<FILEUPLOAD>> |
| 20 | 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. | [[AdditUpload]] <<FILEUPLOAD>> |
| 21 | **Cavity passed all specifications for this traveler: 11, 13, and 21?** If NO option is chosen ensure that appropriate NCR(s) have been issued from this traveler. | [[CavityMeetsSpecifications]] <<YESNO>> |