RF Measurements and Documentation for the Industrial Fabrication of SC Cavities.

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DESY (Hamburg), 28 May 2013

RF aspects of quality control for XFEL cavities

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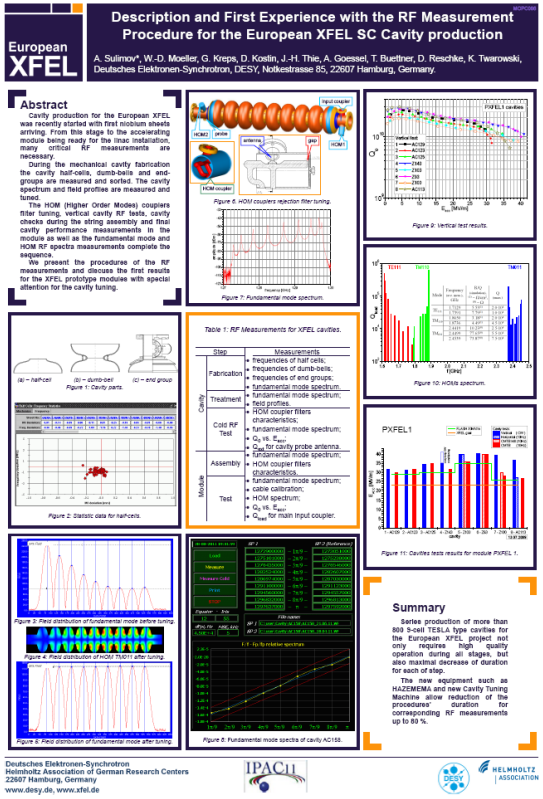
IPAC'11



Description and First Experience with the RF Measurement Procedure for the European XFEL SC Cavity production

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Abstract

Cavity production for the European XFEL was recently started with first niobium sheets arriving. From this stage to the accelerating module being ready for the linac installation, many critical RF measurements are necessary.

During the mechanical cavity fabrication the cavity half-cells, dumb-bells and end-groups are measured and sorted. The cavity spectrum and field profiles are measured and tuned.

The HOM (Higher Order Modes) couplers filter tuning, vertical cavity RF tests, cavity checks during the string assembly and final cavity performance measurements in the module as well as the fundamental mode and HOM RF spectra measurements complete the sequence.

We present the procedures of the RF measurements and discuss the first results for the XFEL prototype modules with special attention for the cavity tuning.

Table 1: RF Measurements for XFEL cavities.

	Step	Measurements
Cavity	Fabrication	• frequencies of half cells; • frequencies of dumb-bells; • frequencies of end groups;
	Treatment	• fundamental mode spectrum;
	Cold RF Test	• fundamental mode spectrum; • field profiles. • HOM coupler filters characteristics; • fundamental mode spectrum; • Q_0 vs. E_{acc} • Q_{ext} for cavity probe antenna.
Module	Assembly	• fundamental mode spectrum; • HOM coupler filters characteristics.
	Test	• fundamental mode spectrum; • cable calibration; • HOM spectrum; • Q_0 vs. E_{acc} • Q_{ext} for main input coupler.

Summary

Series production of more than 800 9-cell TESLA type cavities for the European XFEL project not only requires high quality operation during all stages, but also maximal decrease of duration for each of step.

The new equipment such as HAZEMEMA and new Cavity Tuning Machine allow reduction of the procedures' duration for corresponding RF measurements up to 60 %.

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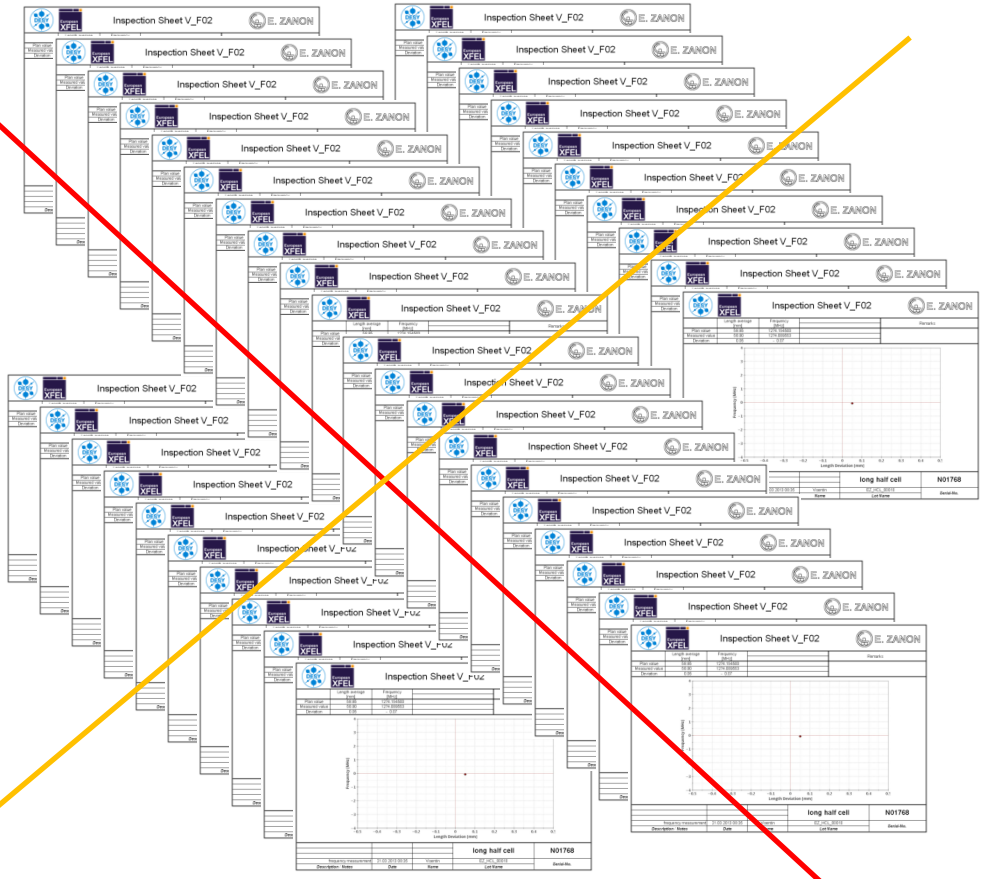
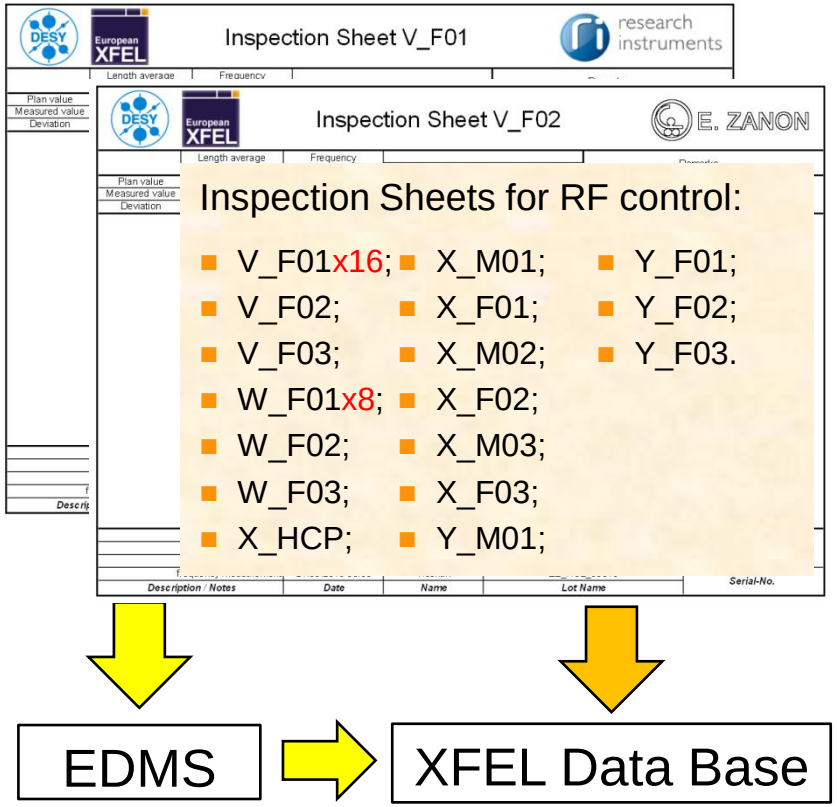


RF aspects of quality control for XFEL serial cavities.

Production Sequence

Production sequence:

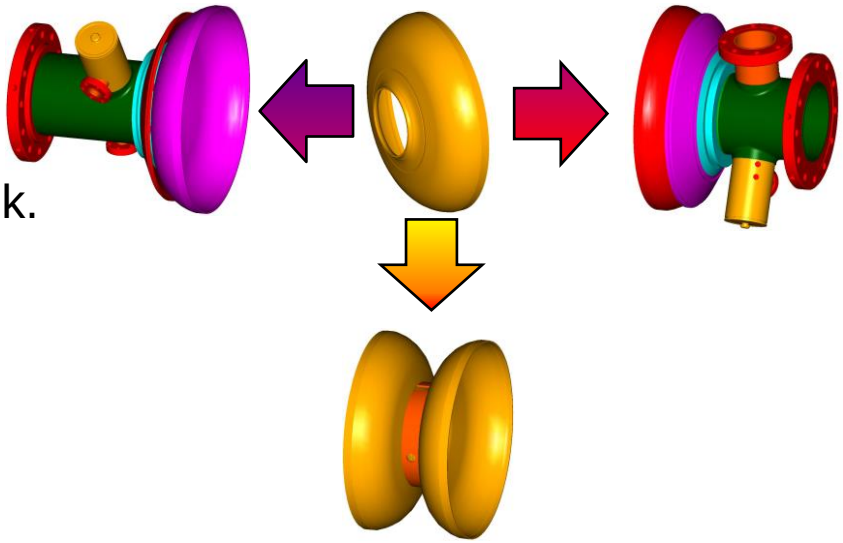
- Cavity parts fabrication,
- Cavity welding,
- Cavity tuning,
- Welding in helium tank (HT),
- Pressure test (PT),
- Cavity transport.



Cavity parts fabrication

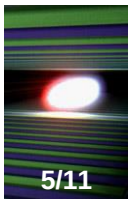
Cavity parts fabrication:

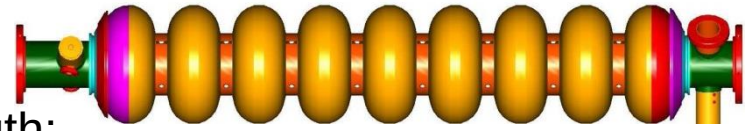
- Shape control for half cells (HC), end groups (EG) and dumb-bells (DB);
- DBs asymmetry control;
- Calculation of optimal parts lengths;
- DBs sorting in cavity;
- Estimation of cavity length in helium tank.



European XFEL

Cavity Welding (Acceptance Level 1)





After cavity welding:

- Measure the pi-mode frequency and cavity length;
- Control the welding parameters (shrinkage and deformation);
- Calculated the cavity length in helium tank.

RF Control after equator welding

Marked: 34 | Details: Cavity parts | Print | Quit

Cavities: CAV00565, CAV00566, CAV00567, CAV00568, CAV00570, CAV00571, CAV00572, CAV00573, CAV00574, CAV00575, CAV00576, CAV00577, CAV00578, CAV00579, CAV00580, CAV00581, CAV00583, CAV00584, CAV00585

Accept

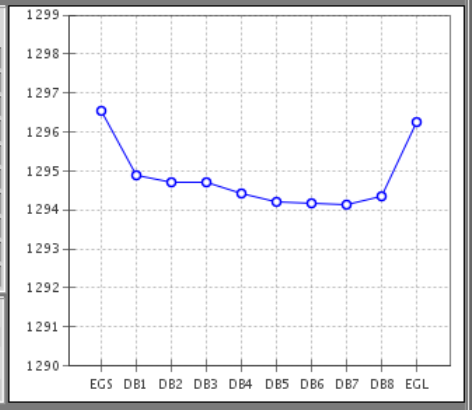
Cavity	Frequency(Pi) [MHz]	Length [mm] according XFEL/014			MAX deviation		Shrinkage [mm]	Material
		After welding	After tuning (expected)	Deviation	Trimming [mm]	Asym. -1		
CAV00544	1298.223	1279.96	1283.40	0.00	0.07	0.07	0.442	T

RF Parts Control

Cavity: CAV00544 | Produced by : Zanon | Shrinkage [mm]: 0.442

		Frequency [MHz]	Length [mm]	Asym.-1	Trimming [mm]
EGS	T00480	1296.525	161.70		0.013
DB1	T01008_T01076	1294.901	116.47	-0.06	-0.020
DB2	T01079_T01225	1294.716	116.57	0.04	0.021
DB3	T01185_T01223	1294.695	116.32	0.02	-0.039
DB4	T00622_T01045	1294.415	116.38	0.05	0.000
DB5	T00783_T00956	1294.198	116.51	-0.03	0.052
DB6	T00784_T01068	1294.156	116.55	-0.01	0.066
DB7	T00655_T01040	1294.145	116.41	0.07	0.032
DB8	T01005_T01099	1294.330	116.61	0.03	0.065
EGL	T00417	1296.248	198.90		0.075

Cavity after welding		Maximum	
1298.223	1279.96	0.07	0.075
		Average	
		0.03	



Remark:

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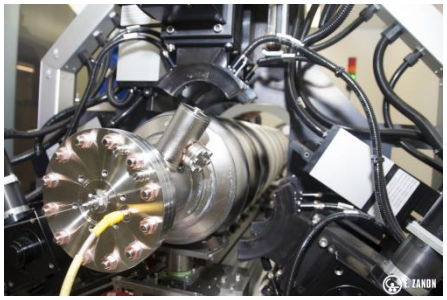
E. ZANON | DESY | HELMHOLTZ ASSOCIATION

Cavity Tuning

Values are controlled during cavity tuning:

- pi-mode frequency,
- field flatness (FF),
- cavity length,
- cavity cells eccentricity.



Cavity measurement on tuning machine at E. Zanon in CTM - station 17

Cavity: CAV00543 Date: 15.Apr.2013 08:48 Field Flatness [%]: 96.82

1Pi/9	2Pi/9	3Pi/9	4Pi/9	5Pi/9	6Pi/9	7Pi/9	8Pi/9	Pi
1272.655	1274.787	1278.178	1282.307	1286.678	1290.904	1294.355	1296.648	1297.393

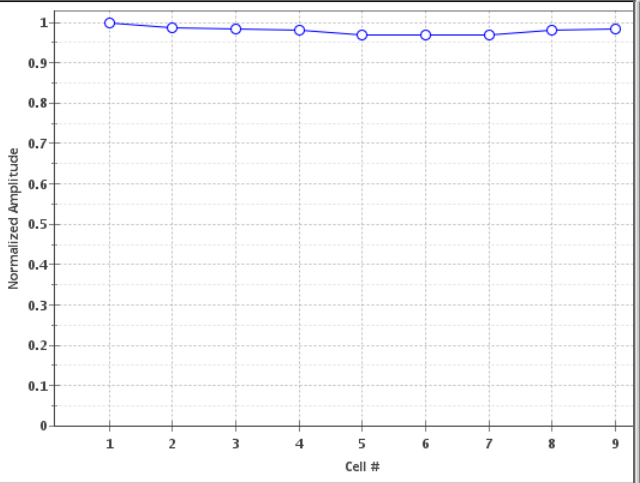
Remark: TANK_10

Spectrum | Compare Spectrum | Tuning Results

Cavity Type: DESY TANK_10
Atmospheric Pressure [mbar]: 1000.00
Air Humidity [%]: 43.30
Room Temperature [°C]: 21.80

Select Mode: Pi

Cell	Amplitude	Norm. Amplitude
1	159.54	1.000
2	157.66	0.988
3	157.03	0.984
4	156.38	0.980
5	154.64	0.969
6	154.61	0.969
7	154.46	0.968
8	156.39	0.980
9	157.03	0.984



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XFEL Cavity Eccentricity: Reconstruction of axis

Cavity: CAV00543 Date: 05.Apr.2013 16:12 Cavity length [mm]: 1058.5

	A-End Conn.Flange	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9	B-End Conn.Flange
Offset [mm]:	0.050	0.070	0.110	0.170	0.140	0.050	0.100	0.080	0.080	0.090	0.040
Angle [deg]:	239	48	59	50	48	80	171	170	181	280	332
X-projection [mm]:	-0.026	0.047	0.057	0.109	0.094	0.009	-0.099	-0.079	-0.080	0.016	0.035
Y-projection [mm]:	-0.043	0.052	0.094	0.130	0.104	0.049	0.016	0.014	-0.001	-0.089	-0.019

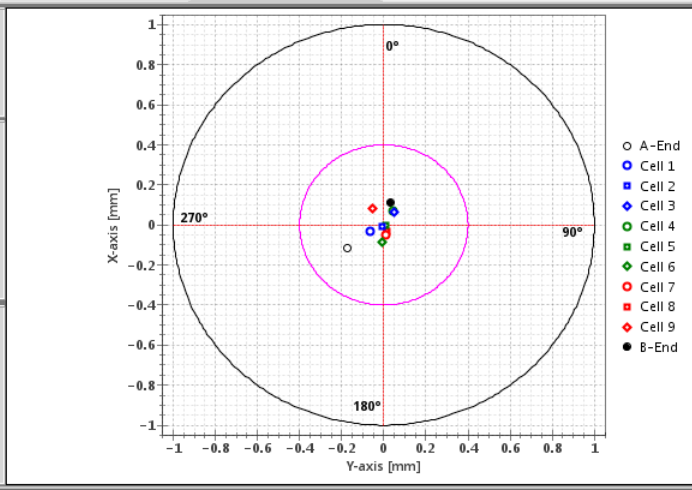
Remark: RB_10

Center Offsets | Reconstruction of Axis | Center Offsets (New Axis)

Max. Deviation [mm]
dR @ Cell 9: 0.096

A - End Connecting Flange
dX @ A [mm]: -0.118
dY @ A [mm]: -0.173

B - End Connecting Flange
dX @ B [mm]: 0.111
dY @ B [mm]: 0.030



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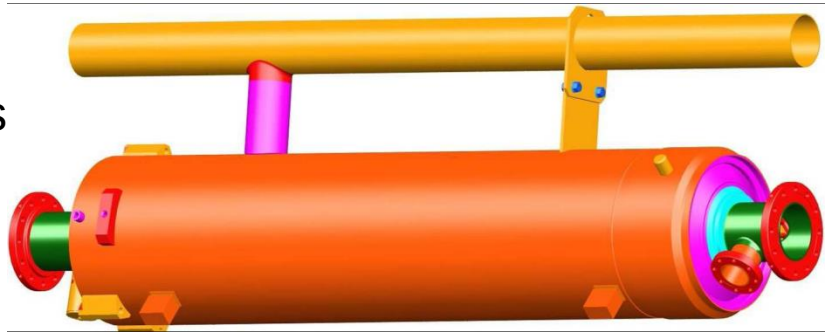
Welding in Helium Tank and Pressure Test (Acceptance Level 2)

Welding in helium tank, pressure test:

- Control of pi-mode frequency during the rings with bellow and HT welding;
- Checking of RF parameters (Fpi, FF) before and after HT and PT.



RF Control after Acceptance Level 3

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Cavities: CAV00528, CAV00529, CAV00530, CAV00531, CAV00534, CAV00535, CAV00537, CAV00538, CAV00539, CAV00540, CAV00541, CAV00543, CAV00544, CAV00545, CAV00546, CAV00547, CAV00551, CAV00552, CAV00558

Accept

Cavity	Frequency (Pi) [MHz]			Transmission [dB]	Spectrum deviation [kHz]	Field flat. (in HT)	Length [mm]	Maximum eccentricity [mm]	Warning
	Deviation (in HT)	in HT (Y_F02)	with vac (Y_F03)						
CAV00543	0.037	1297.393	1297.680	124	2.5	0.97	1058.49	0.17	
CAV00544	0.042	1297.388	1297.680	126	2.5	0.96	1058.58	0.26	
CAV00545	0.055	1297.375	1297.681	126	5.0	0.94	1058.54	0.22	
CAV00546	0.028	1297.458	1297.738	126	1.9	0.97	1058.93	0.28	

Detail RF Data Control

Cavity: CAV00543 Produced by : Zanon

Source	Frequency(Pi) [MHz]	Field flatness	Frequency deviation [MHz]	Spectrum deviation [kHz]	Comments / Remarks
X_F02	1297.451	0.98	0.001		OPEN_10
X_F03	1297.397	0.99	0.033		FMS_10
Y_F01	1297.408	0.97	0.022		RB_10
Y_F02	1297.393	0.97	0.037	2.5	TANK_10
Y_F03	1297.680		-0.070		Final spectrum, for Pi-mode reference value must be (1297.75 +/- 0.1) MHz

Source	Length [mm]	Max ECC [mm]	Comments / Remarks
X_M02	1058.53	0.19	OPEN_10
X_M03	1058.51	0.17	FMS_10
Y_M01	1058.49	0.17	RB_10

Print | Close

Cavity Transport (Acceptance Level 3)

To estimate Field Flatness (FF) changes the two spectra have to be compared:

- Reference spectrum SP2 can be downloaded from XFEL DB (it's a spectrum with known value of FF^{ref})
- N = 9 – number of cavity cells, measured spectrum SP1 = $\{f_i\}$, SP2 = $\{F_i\}$, where i = 1…N.
- Relative spectrum is calculated as:

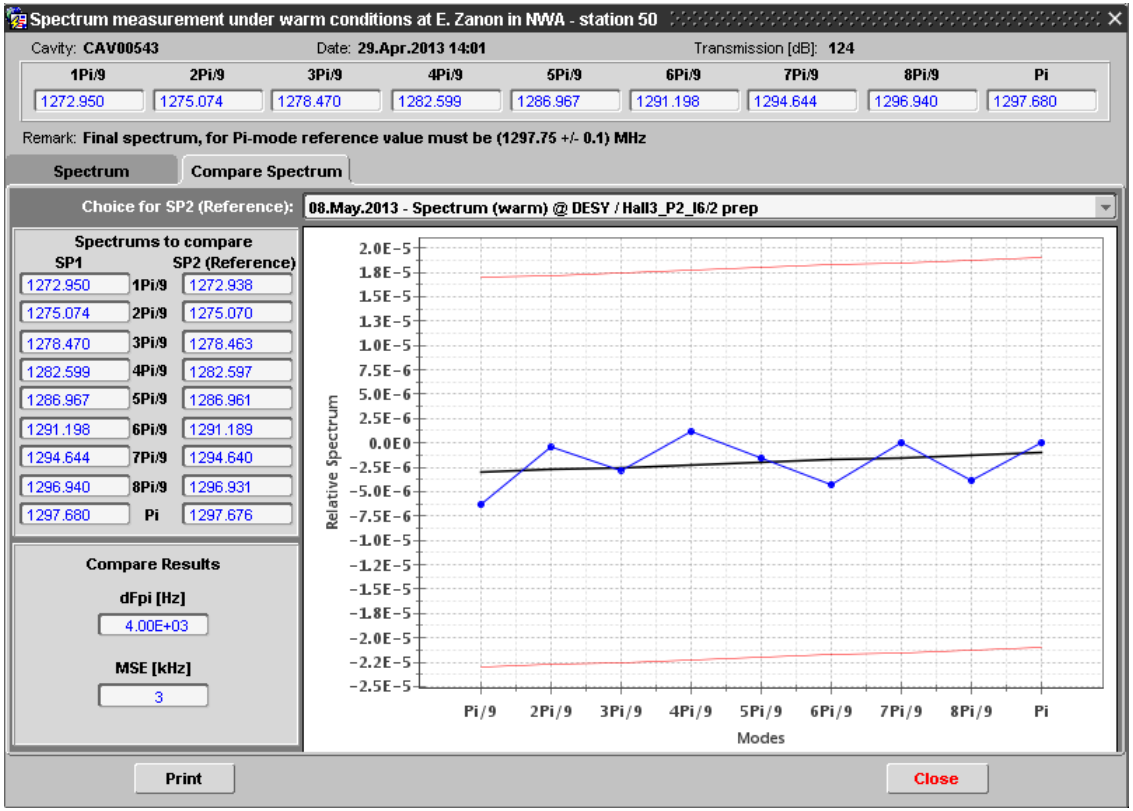
  $RS = \{R_i\} = \{F_i/f_i - F_N/f_N\}$, where i = 1…N.
- Linear Fit is calculated for relative spectrum:

  $L = \{L_i\} = linear\_fit\{R_i\}$, i = 1…N
- Mean squared error is calculated as:

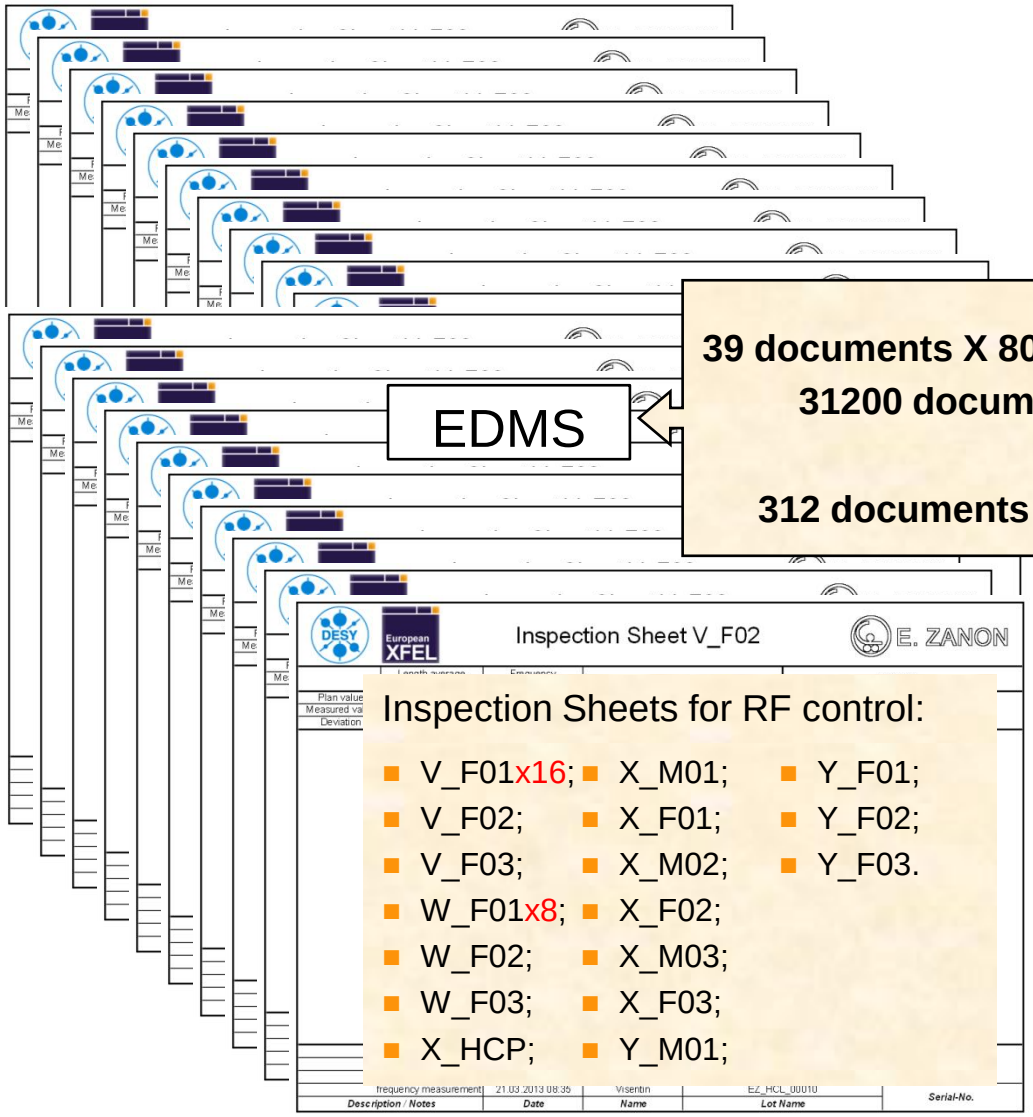
$$mse = \sum_{i=1}^{N} (R_i - L_i)^2 \Big/ N$$

- Mean spectrum frequency deviation is calculated as:

$$MSE\,[kHz] = \sqrt{mse} \times f_\pi^{op}, f_\pi^{op} = 1.3GHz$$

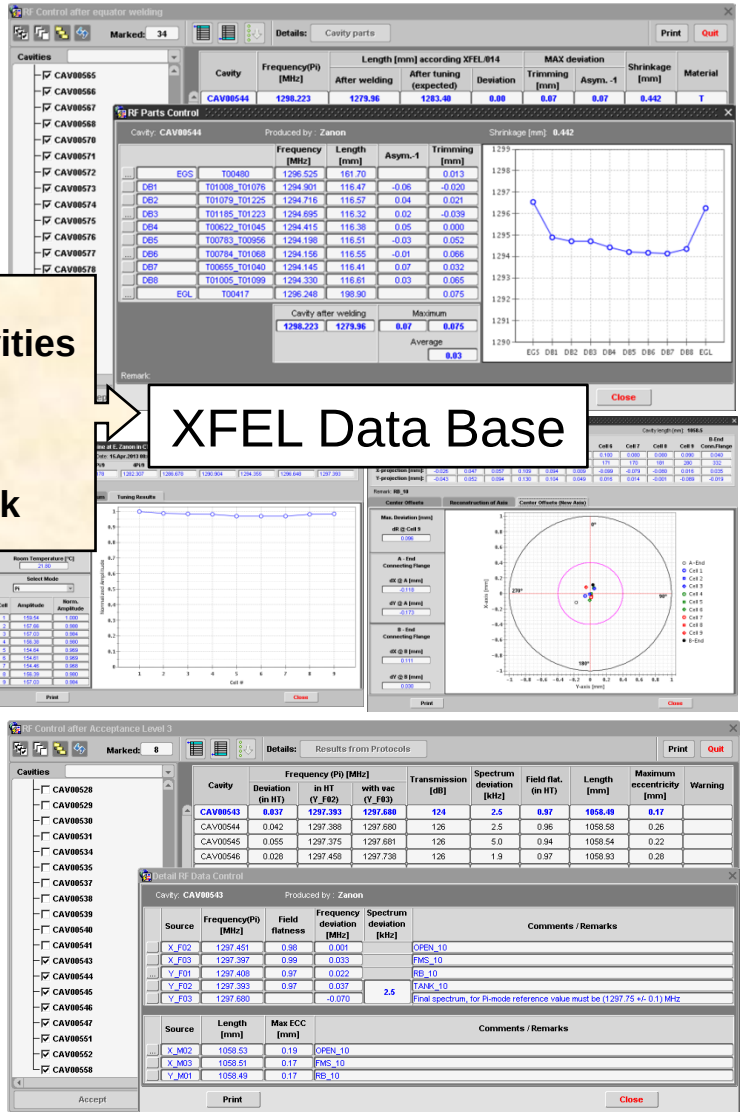


Conclusion



39 documents X 800 cavities
31200 documents

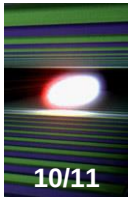
312 documents / week



Inspection Sheets for RF control:

- V_F01x16;
- V_F02;
- V_F03;
- W_F01x8;
- W_F02;
- W_F03;
- X_HCP;
- X_M01;
- X_F01;
- X_M02;
- X_F02;
- X_M03;
- X_F03;
- Y_M01;
- Y_F01;
- Y_F02;
- Y_F03.

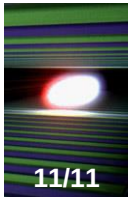
Acknowledgements



We appreciate:

- company **E.Zanon** for possibility to present the data.
- **IPP** DESY **group** for supporting the EDMS and data transfer.
- DESY **Data Base Team** for organizing the automation of data analysis.

THANK YOU !



Thank you all for attention !