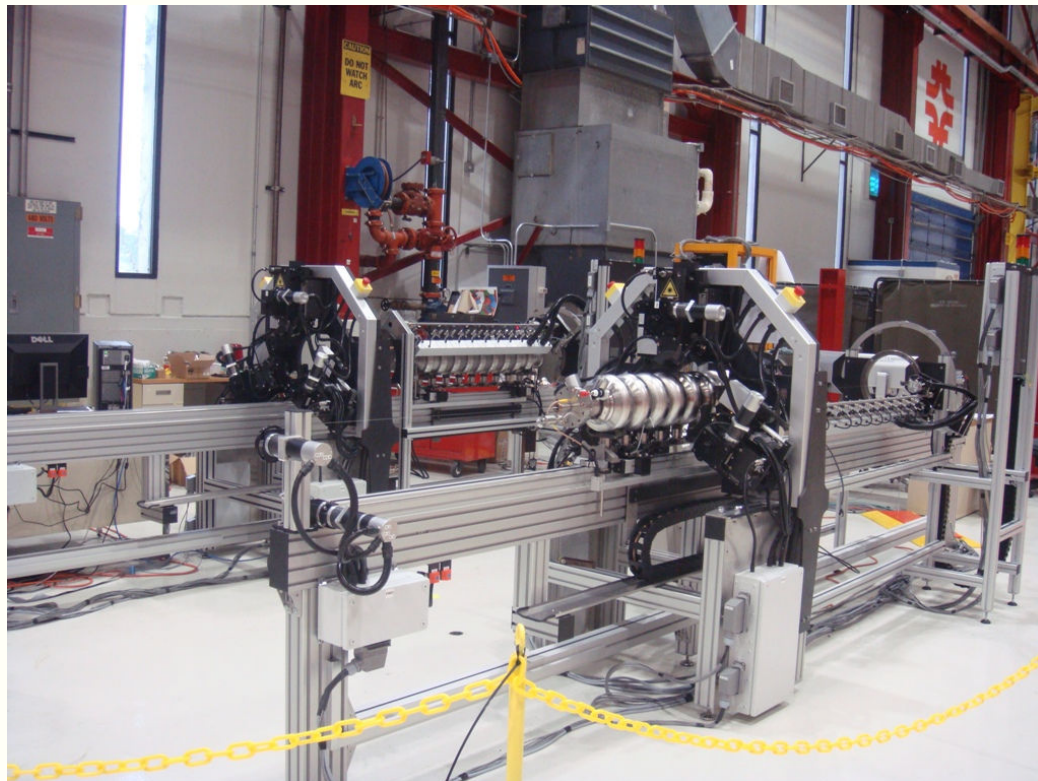# Cavity Tuning Machines Project Update

Ruben Carcagno

January 11, 2010

Cavity Tuning Machines Status

DESY and KEK machines at Fermilab Industrial Center Building (ICB)

- **DESY delivered the FNAL and KEK machines mechanical assemblies to FNAL on August 2009**

- **A few mechanical parts need to be redesigned and fabricated, DESY expects delivery of final parts by end of January 2010**

Analog Inputs	Digital Inputs	Motor Outputs	Digital Outputs	TOTAL I/O
21	35	9	19	84

# Control Rack Fabrication Status

First production control rack fabrication in progress

- **Design complete and fully tested with prototype rack**
- **First production control rack completed by mid-January 2010**
- **All four production control racks completed by end of April 2010**
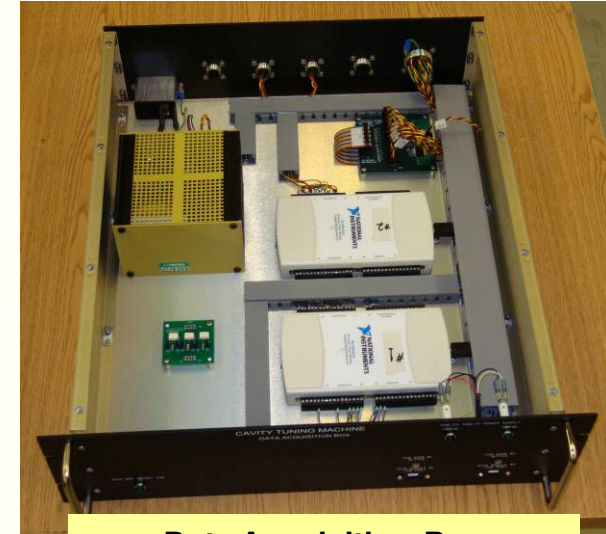- **Each control rack include five FNAL-developed electronics boxes**

FNAL Electronic Boxes

Emergency Trip System Box
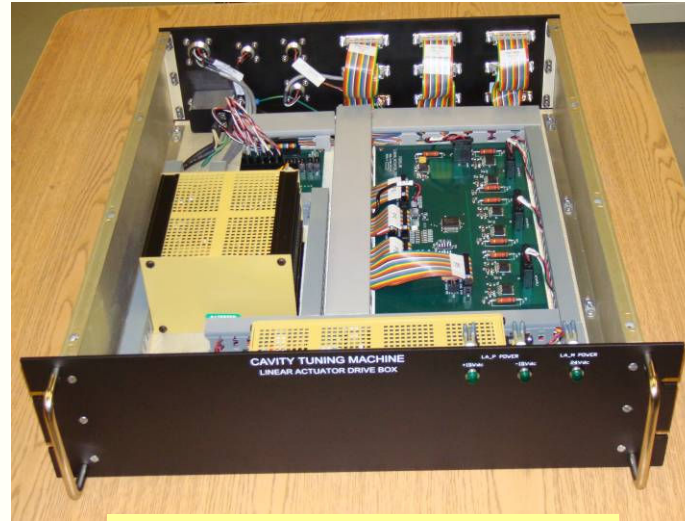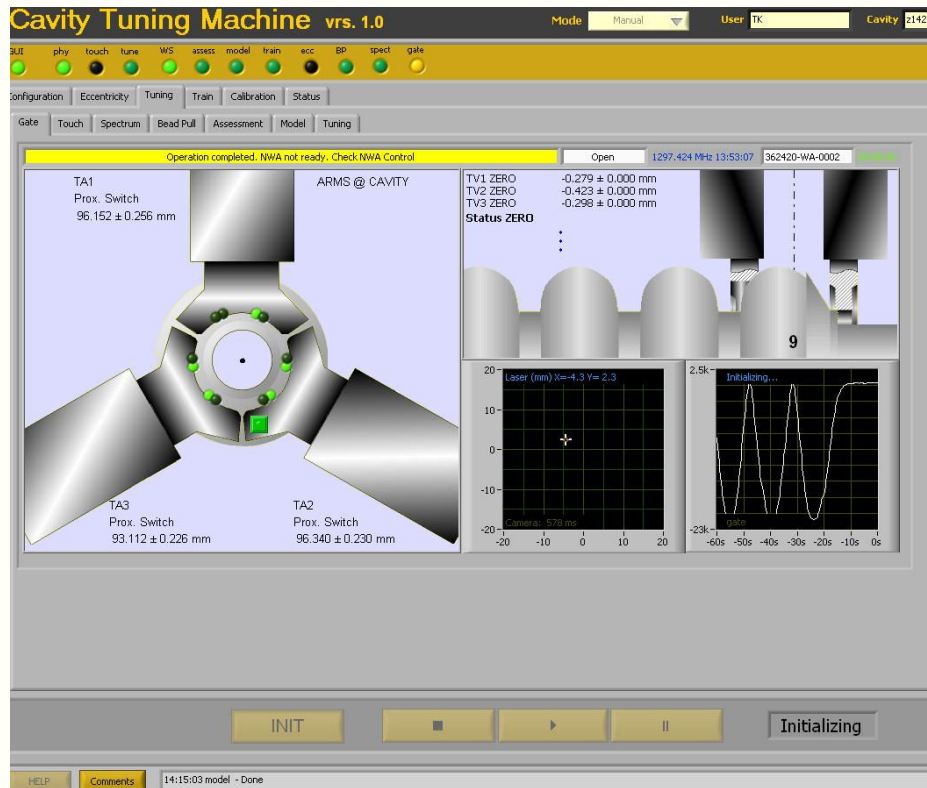

Linear Actuator Drive Box

Data Acquisition Box

Motion Inhibit Box

Manual Control Box

Software Development Status

Operator display example

- Plug-in examples: cavity model, eccentricity measurement, bead-pull measurement, spectrum measurement, gate service, train positioning, touch service, tuning, eccentricity model, monitoring GUI

- **Based on a framework/plug-in architecture**
- **Framework developed and tested, automation features included**
- **Most plug-ins developed and tested: all functions for tuning a cavity are available**
- **More testing and debugging needed for exception handling, reliability. Automatic eccentricity correction mechanical model under development**
- **First complete release by April 2010**
- **Additional automation and speed expected to evolve as more operational experience is gained**

9-cell Cavity Tuning
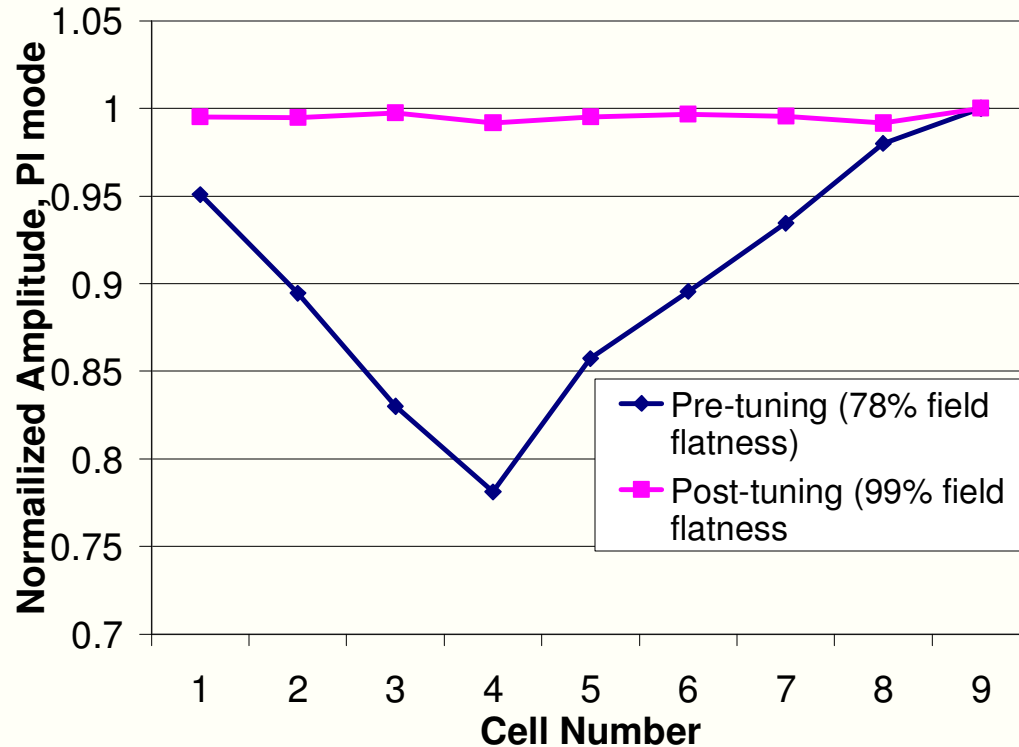
- **Tuning of a 9-cell cavity with the FNAL-developed control system demonstrated on December 2009**

- **Results:**

    - **Field flatness from 78% to 99%**

    - **Deviation from target frequency from -430 KHz to -6 KHz**

    - **Cavity kept straight**

Tuning Model
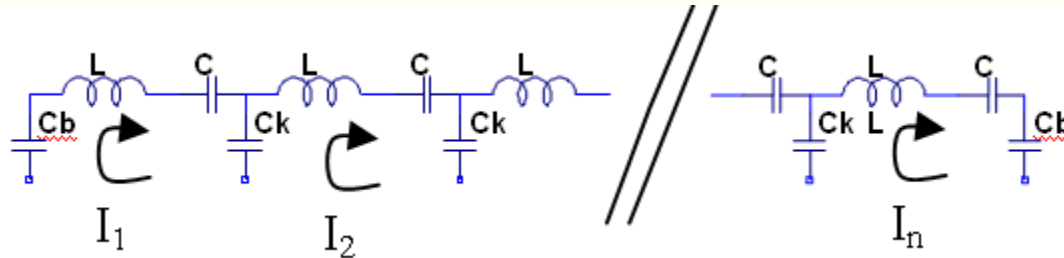
n-pole lumped parameter model of coupled LC oscillators, with automated phase assignment algorithm

Model input: target frequency, modal frequencies, frequency shifts during bead pull at each mode

TargetFrequency [MHz]
1297.4   Enter the required target frequency for the cavity in current conditions

RelativeFieldStrength

0	36.3456	111.088	172.08	212.925	234.701	212.347	170.228	108.883	34.1396
0	79.6375	196.756	219.468	143.089	5.87282	141.596	221.558	199.382	79.7746
	114.147	225.136	114.178	105.324	223.712	106.621	113.332	221.393	112.708
	145.452	188.861	81.1844	217.098	5.60625	217.601	78.5301	187.65	145.881
	169.244	108.916	205.075	44.8338	217.599	43.3196	205.976	108.568	173.013
	192.028	4.4587	186.056	187.379	3.61248	190.344	183.572	5.60892	193.262
	207.238	107.435	41.8871	167.902	210.38	165.552	38.0865	109.595	205.522
	211.529	185.591	140.024	75.0957	14.1894	78.0684	142.192	188.039	211.336
	149.547	149.467	151.486	149.92	144.679	149.256	149.376	147.763	146.254

Frequency [Hz]

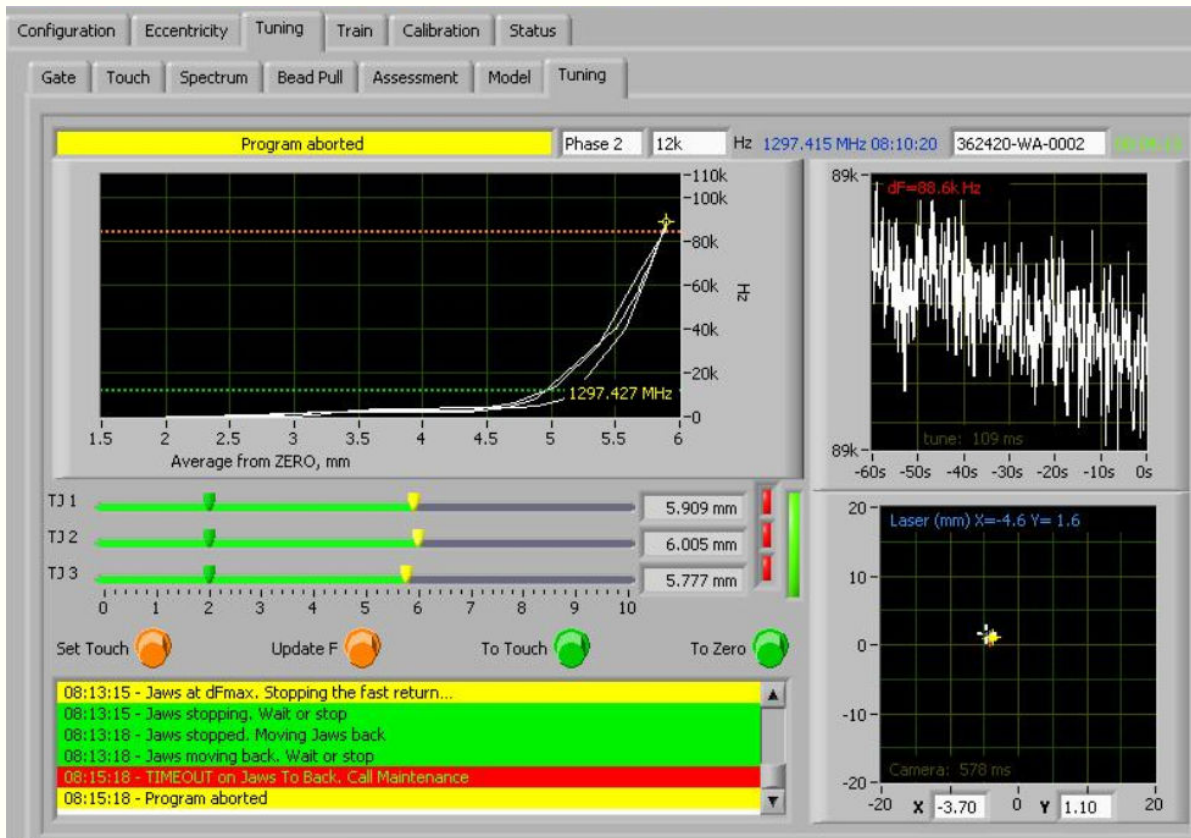|	
0	1.2731E+9
	1.27531E+9
	1.27845E+9
	1.28263E+9
	1.28683E+9
	1.29107E+9
	1.29432E+9
	1.29661E+9
	1.29735E+9

Bead pull measurements   **Spectrum measurements**

Model output: PI-mode target frequencies as each cell is tuned in turn

|	dF,kHz		TargetFrequency [MHz]
0	5.40046	0	1297.35
	15.1023		1297.37
	-10.2978		1297.36
	-9.68053		1297.35
	49.5008		1297.4
	-13.1515		1297.38
	-2.2404		1297.38
	5.88779		1297.39
	13.1038		1297.4

Tuning Algorithm

- **Program automatically moves tuning jaws to achieve model dF while keeping laser spot centered**

- **PI-mode frequency feedback provided by network analyzer**

- **For eccentricity corrections, program will move tuning jaws while shifting laser spot to new (x,y) coordinate provided by mechanical model (under development)**
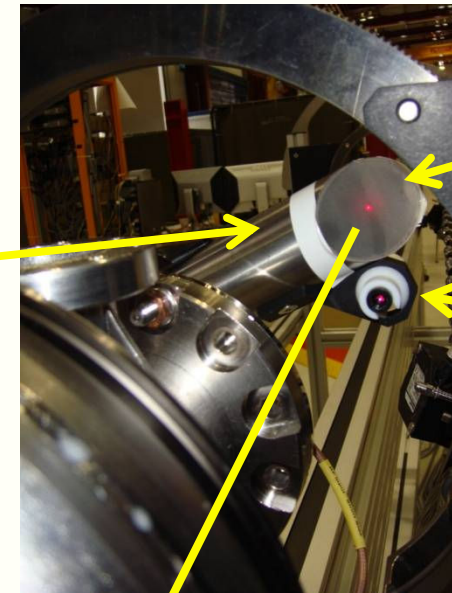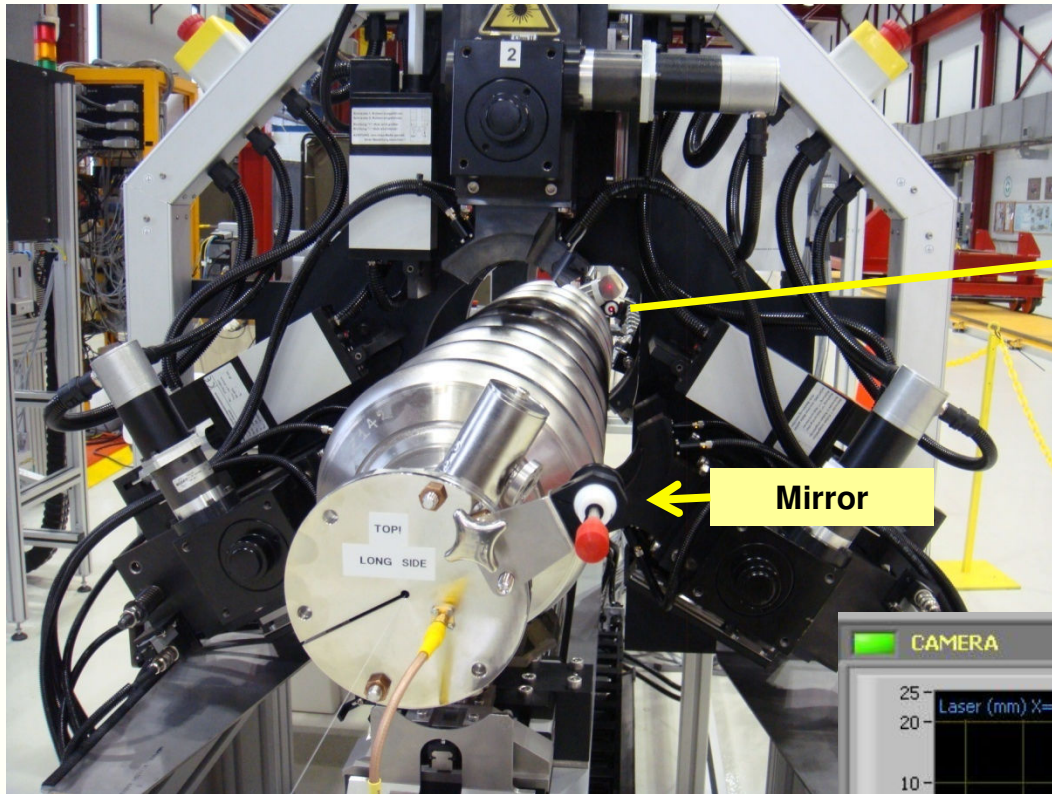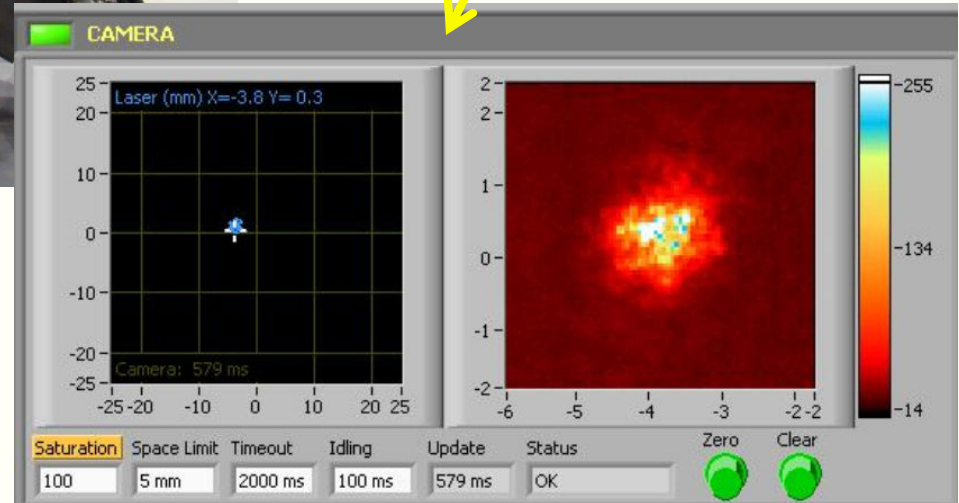
Cavity Alignment Laser

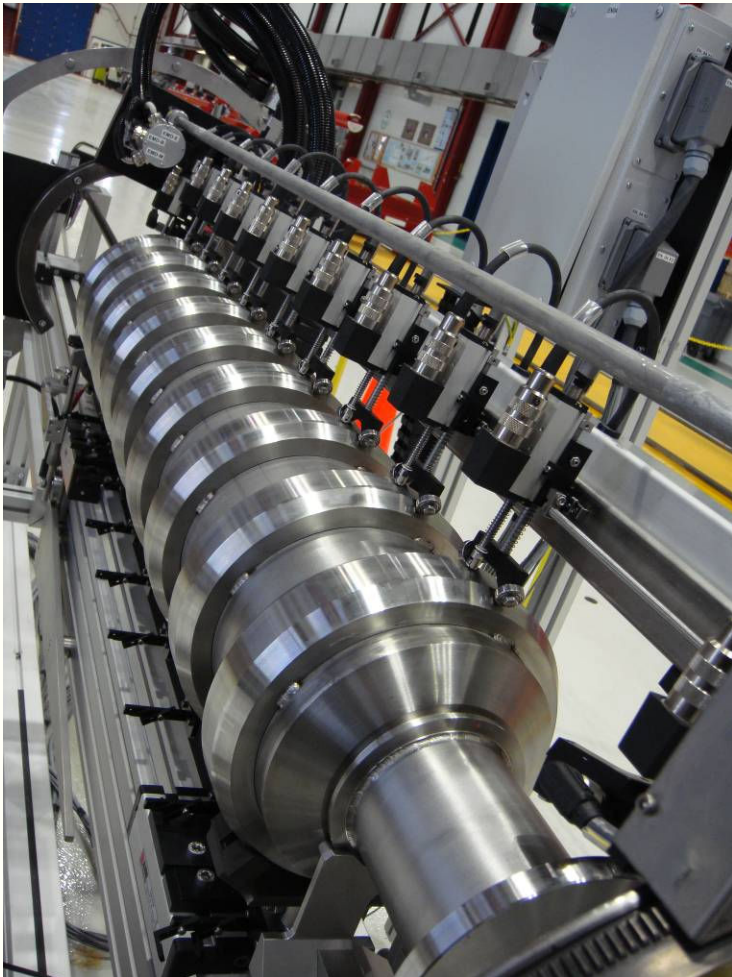- **Cavity alignment laser spot captured with camera and digitized**
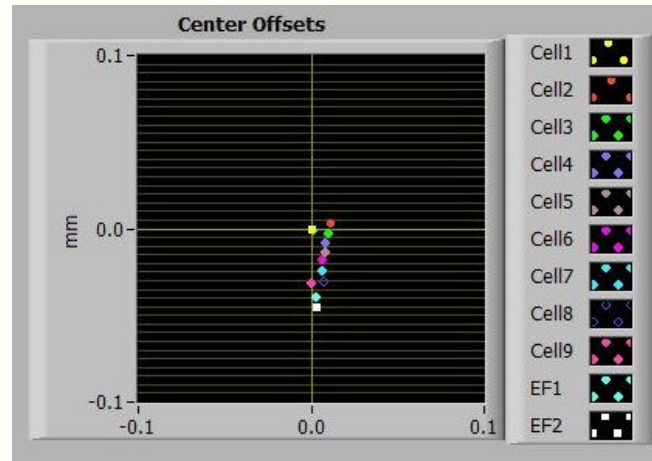- **Key to enable tuning automation**

Eccentricity Measurements

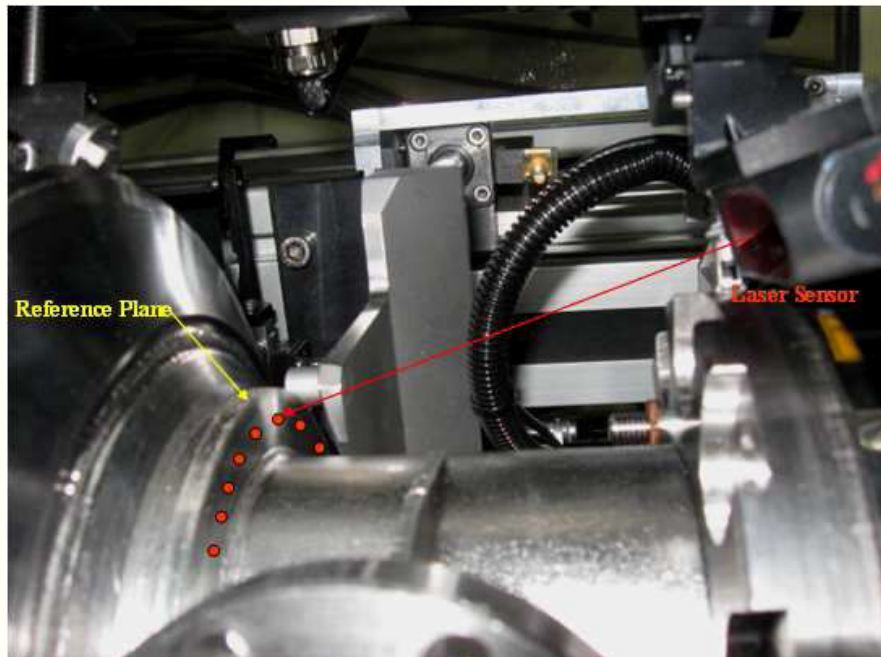**Calibration with "dummy" cavity**

Dummy cavity eccentricity measurements

**Target: offsets within 1 mm diameter for cells, and 2 mm diameter for end flanges**

Center Offsets

Cell1
Cell2
Cell3
Cell4
Cell5
Cell6
Cell7
Cell8
Cell9
EF1
EF2

Flange Angles

Flange1- Angle
169

Flange1- Amplitude
0.01

Flange2- Angle
-59

Flange2- Amplitude
0.02
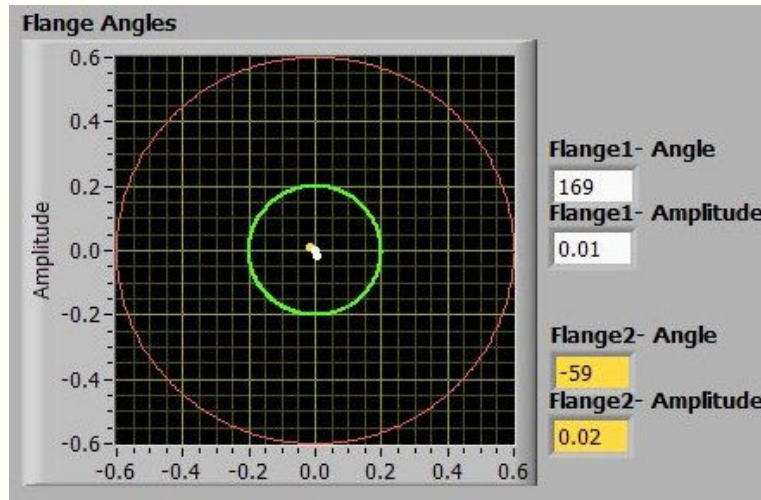
Target: 0.2 mm amplitude deviation

Reference Flange Perpendicularity

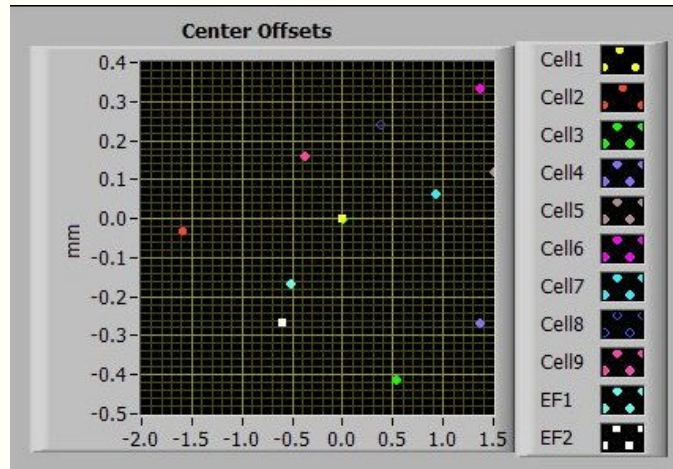**Reference Flange Laser Measurements**

Tolerance: dL < 0.2 mm

- **Reference flange perpendicularity is critical for welding He vessel to XFEL cavities**
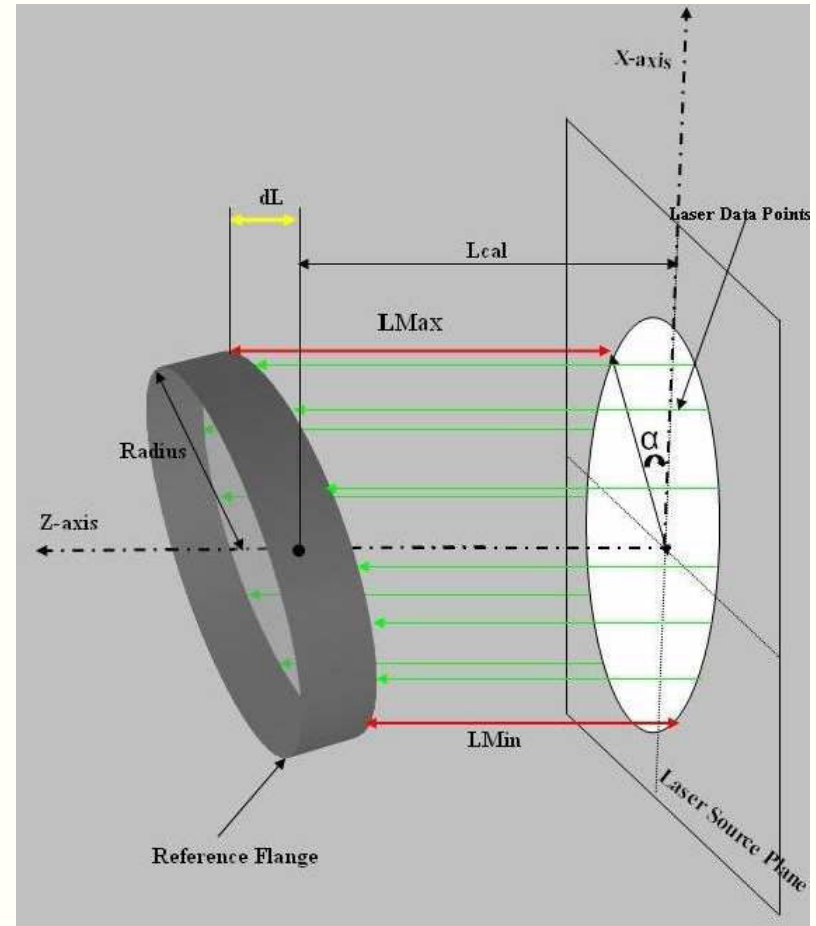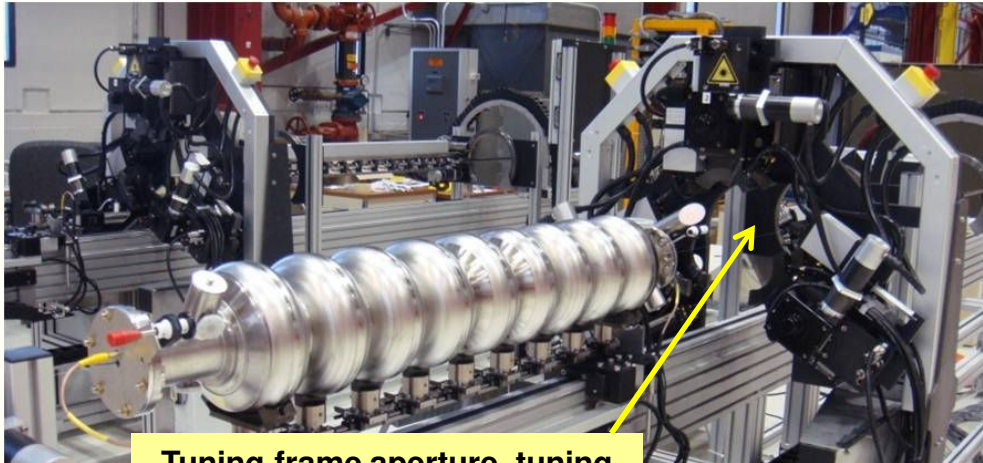
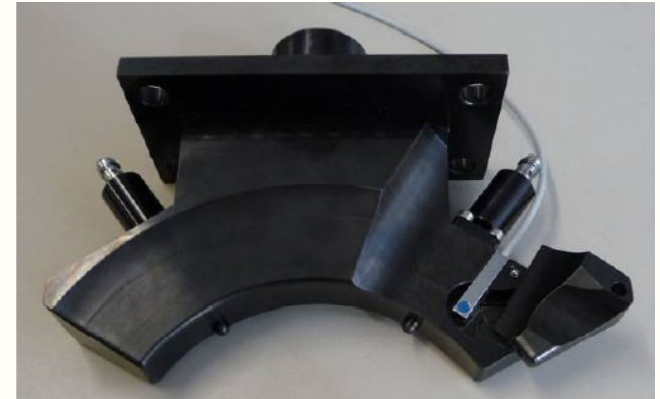# Eccentricity Measurements
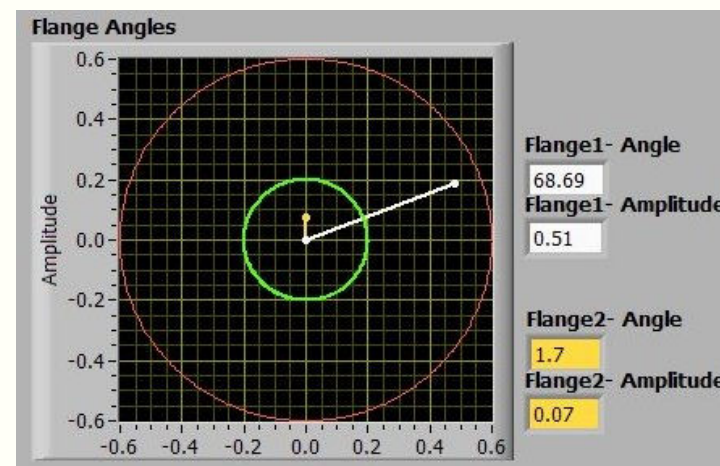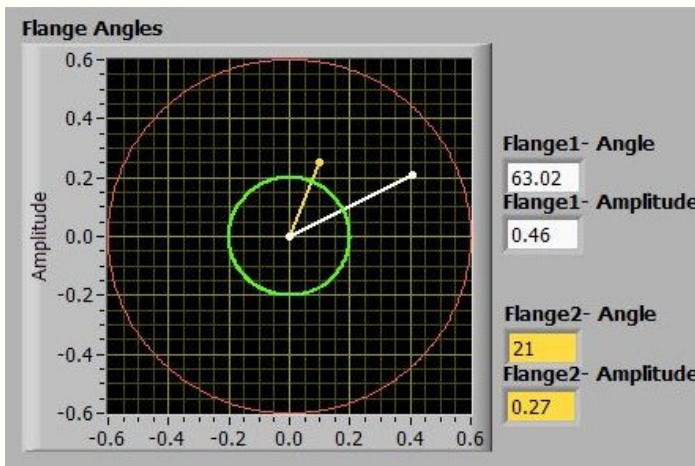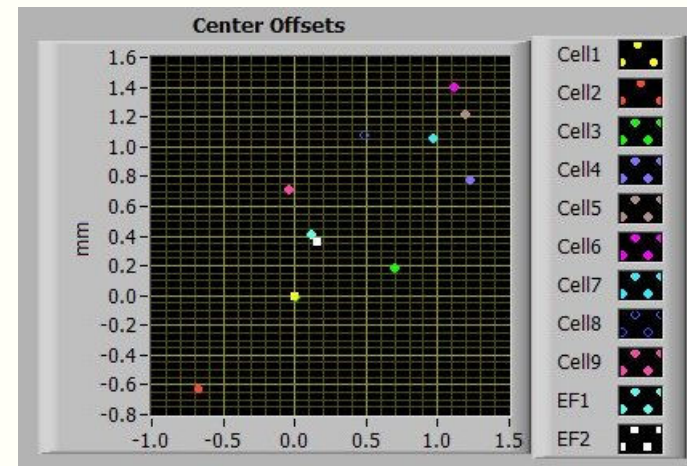
Cavity Tuning Machines Cost

- **MOU cost estimate per machine: $492 K**
    - MOU specified labor rate of 70 kEuro per person-year, with an exchange rate of 1 Euro = 1.4462 US$ on Nov. 05, 2007
- **Actual cost reported below as of End of Calendar Year 2009 (EOCY09). Used 1,760 labor hours per FTE**
- **DESY cost to EOCY09 (from Wolf-Dietrich Moeller, 12/22/09)**
    - Labor: 12,829 hours, 7.3 FTEs, $739 K
    - M&S: $813 K
- **FNAL cost to EOCY09 (from TD Project 3000 accounting, 1/6/10)**
    - Labor: 10,838 hours, 6.2 FTEs, $623 K
    - M&S: $209 K
- **Total cost to EOCY09 (4 machines): $2,384 K**
- **Total cost to EOCY09 per machine: $596 K**
    - Final cost per machine to be determined ~ April 2010
- **KEK contributions (direct):**
    - JFY07: $71,885, JFY08: $223,873, JFY09: $197,239
    - Total KEK contributions to EOCY09: $493 K
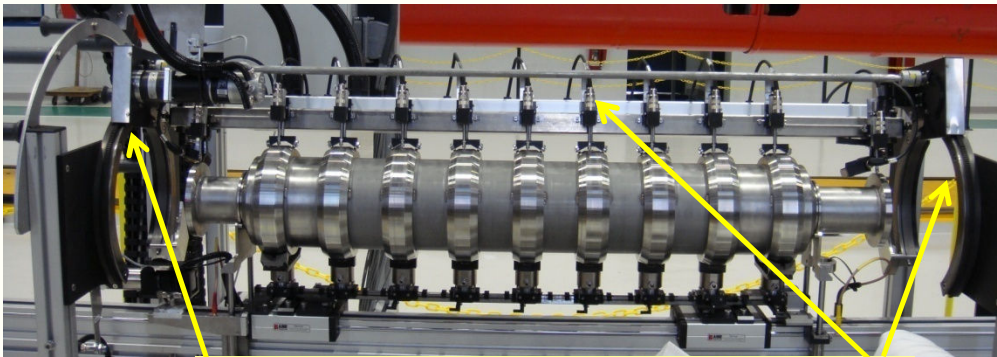
Main Changes for 650 MHz cavities

Tuning frame aperture, tuning vise aperture

Tuning Jaws (x6)

Eccentricity Measurement System, Dummy Cavity

Protective Shields (x10)