LP and HP RF measurements

Acknowledgements: S. Ramberger, F. Grespan, A. Lombardi, J.M. Giguet, J. M. Balula, M. Delrieux , J. Broere, R. De Prisco, P. Maesen, C. Nicou, D. Piednoir, G. Vandoni, E. Page, C. Jarrige, M. Widorski

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Outline

- Low power measurements (structure and post-couplers modes, working frequency, Q_0, Q_L, β)
- High power measurements (cavity acceptance test, PMQs test)

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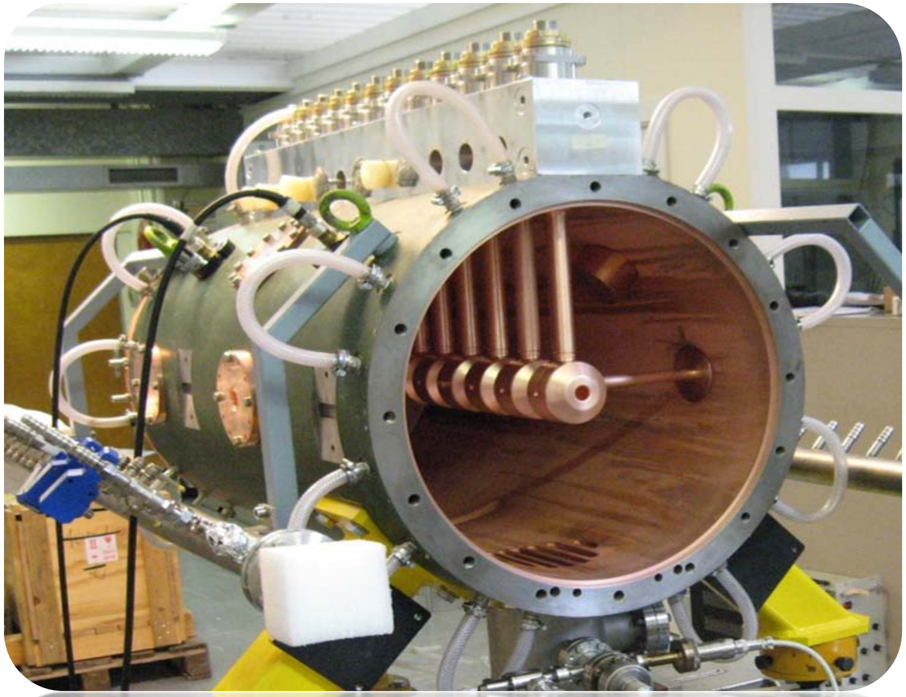
Linac4 DTL prototype



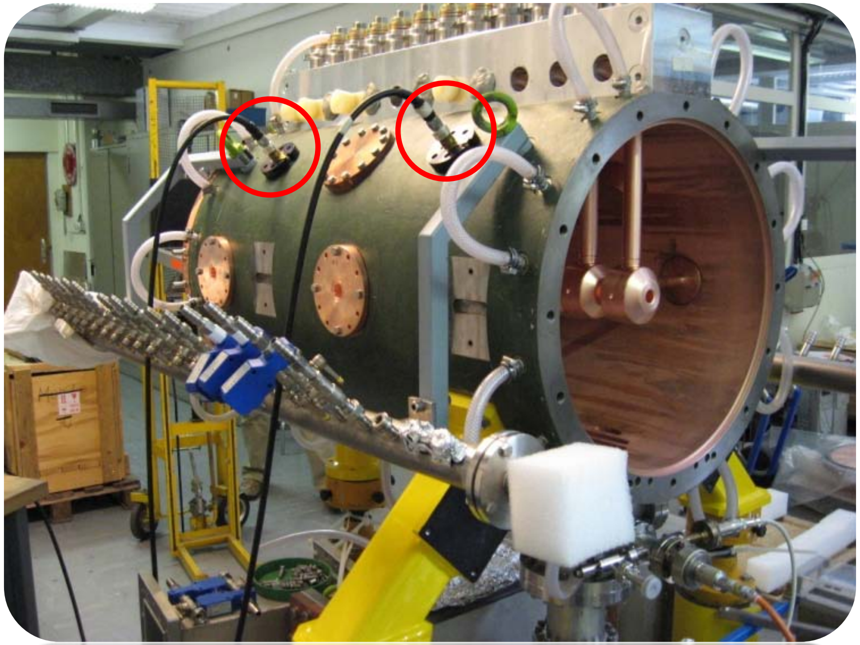
Characteristics (designed)

- Frequency=352.2MHz; Q_0=34000
- D=520mm; d=450mm
- Length =1034mm
- 13 cells; DT period=1βλ; PCs period 3βλ.
- PCs diameter=20mm
- 3MeV-5.4MeV (β=0.08-0.11)
- E_0=3.3MV /m

12 DTs, 3 tuners, 4 post-couplers, 1 RF iris-port, 1 vacuum grid and 2 pick-ups

Pick-ups, vacuum and RF tightness

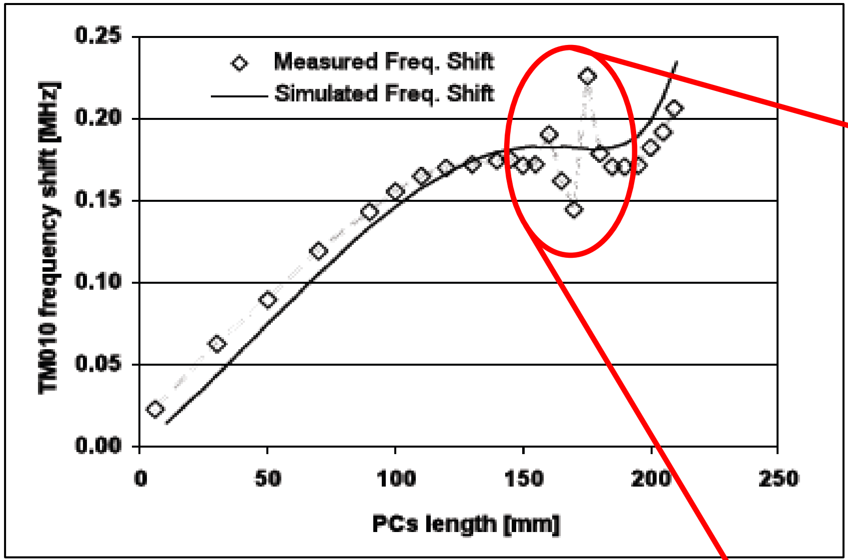
- Low power measurements have been performed in order to find the resonance frequency, quality factor Q_{cav} of the cavity ,coupling parameter beta of the iris coupler and post-couplers length.
- Two pick-ups for low power measurements and RF monitoring in high power operation.



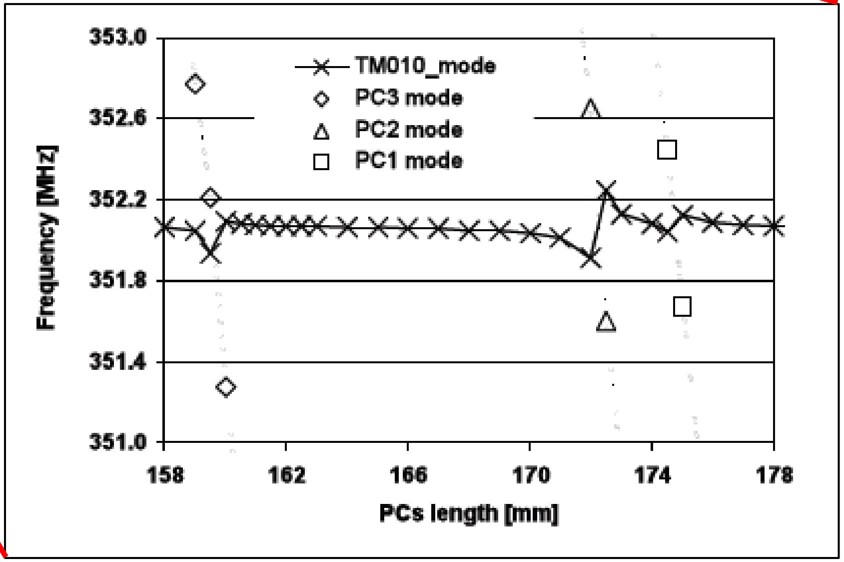
The resonance frequency with all tuners completely inserted (5 cm inside) and post couplers at nominal length is f_0 = 351.973 MHz, lower than the designed frequency because of a re-machining step which enlarged the tank diameter by about 1.2 mm.

Post-couplers tuning

$$df = f \cdot \frac{\int_{\Delta V} \left(\mu H^2 - \varepsilon E^2\right) dV}{4U} = \pi R^2 \cdot dr \cdot f \cdot \sum \frac{k_{cyl}\mu H^2 - k_{cyl}\varepsilon E^2}{4U}$$

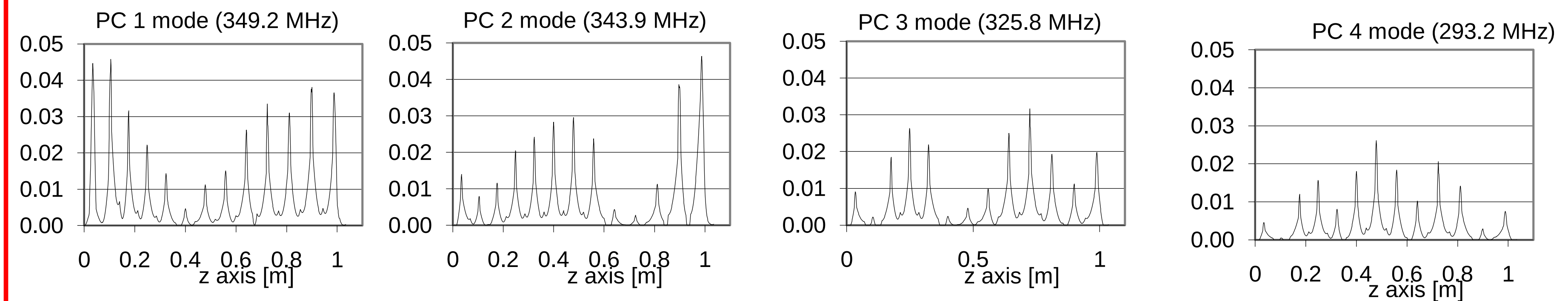


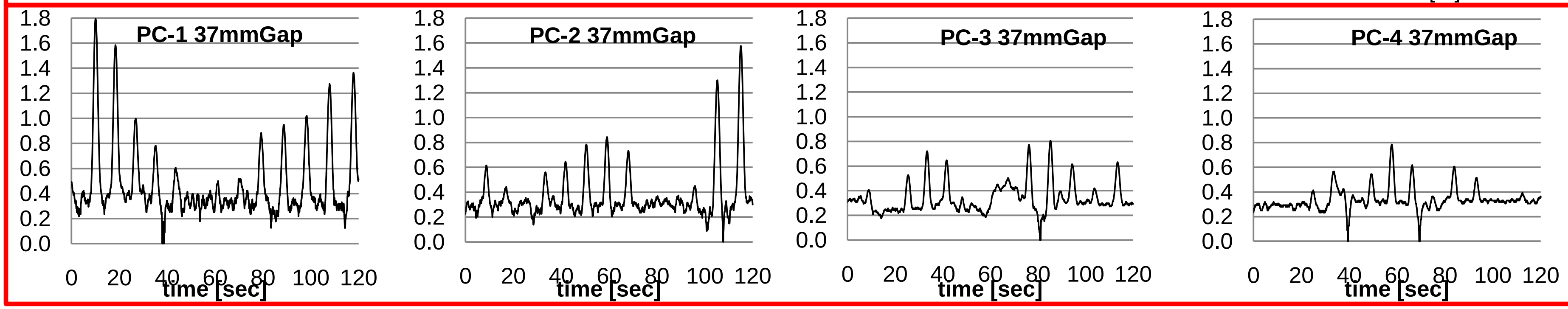
3 highest modes of the post-couplers band cross the TM_{010} mode and interact with it.

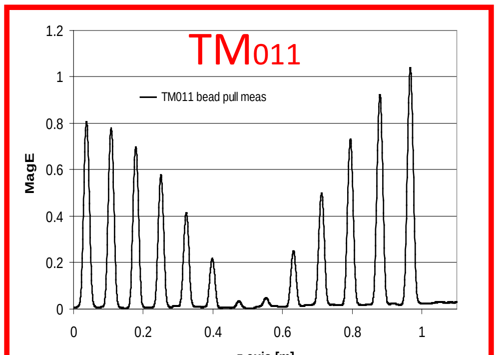


See F. Grespan talk
for details on post-couplers

Post-couplers induced field



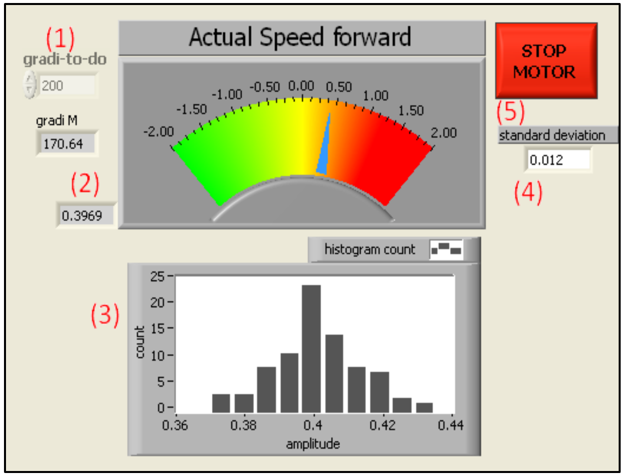


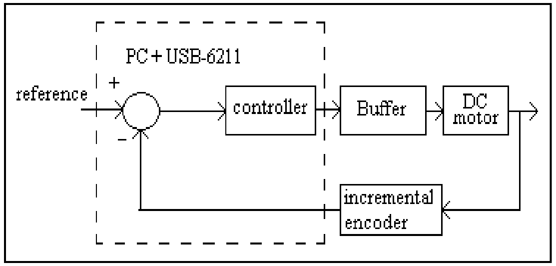


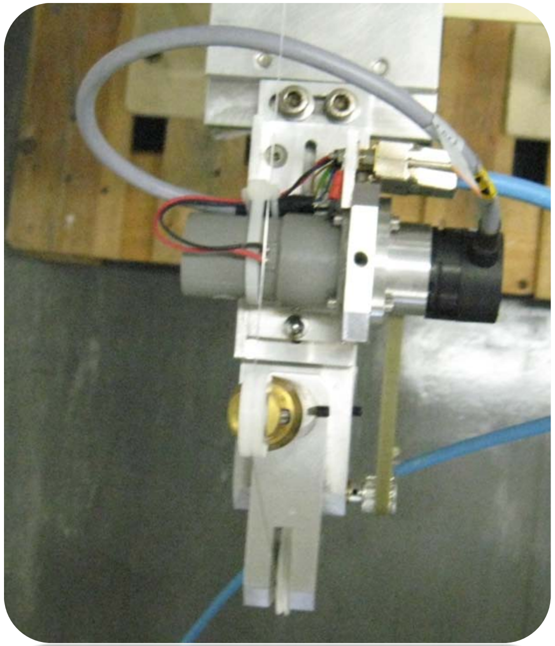
The highest PC mode (PC_1 mode) presents the same axial field pattern as the TM_{011} mode. For this reason the PC_1 mode has a stabilizing effect with respect to perturbations induced by the TM_{011} mode on the accelerating field.

Bead-pull system

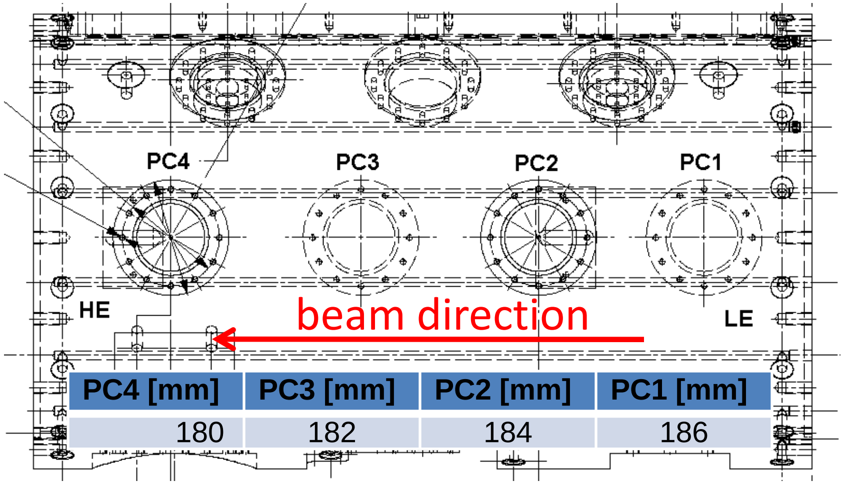
- DC motor
- Motor speed control
  - DAQ board
  - incremental encoder
- Continuous acquisition points
  - network analyzer
  - LabVIEW
- Matlab post-processing



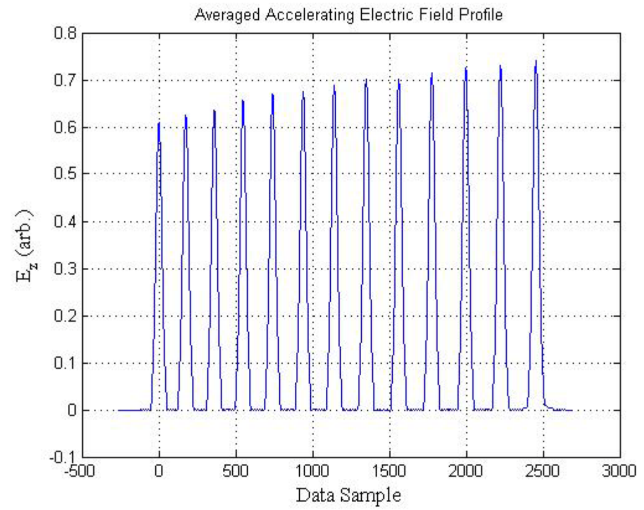


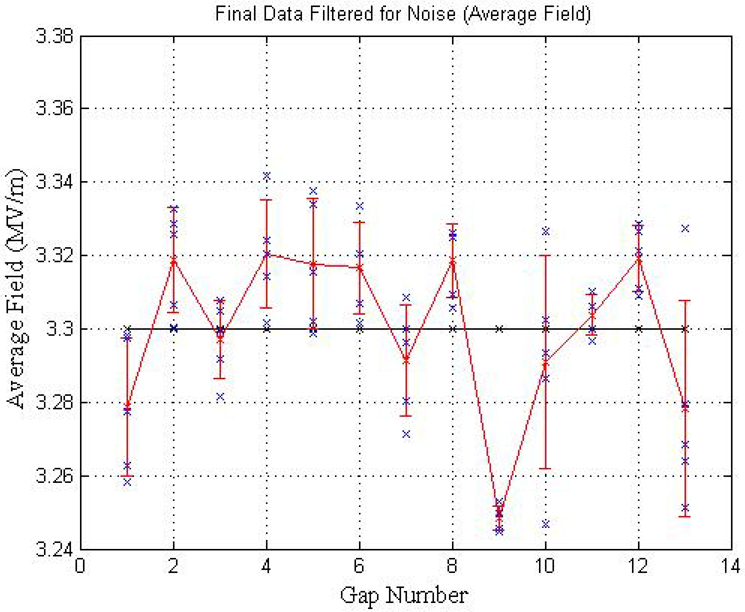


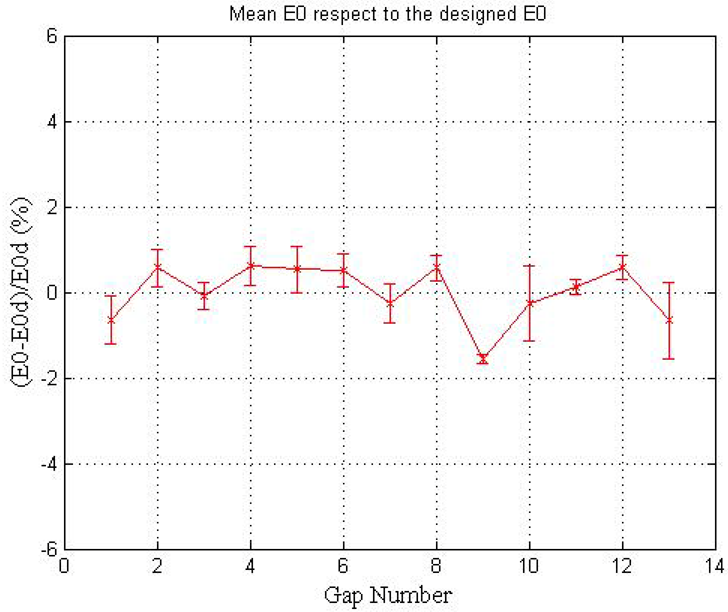
Bead-pull measurements



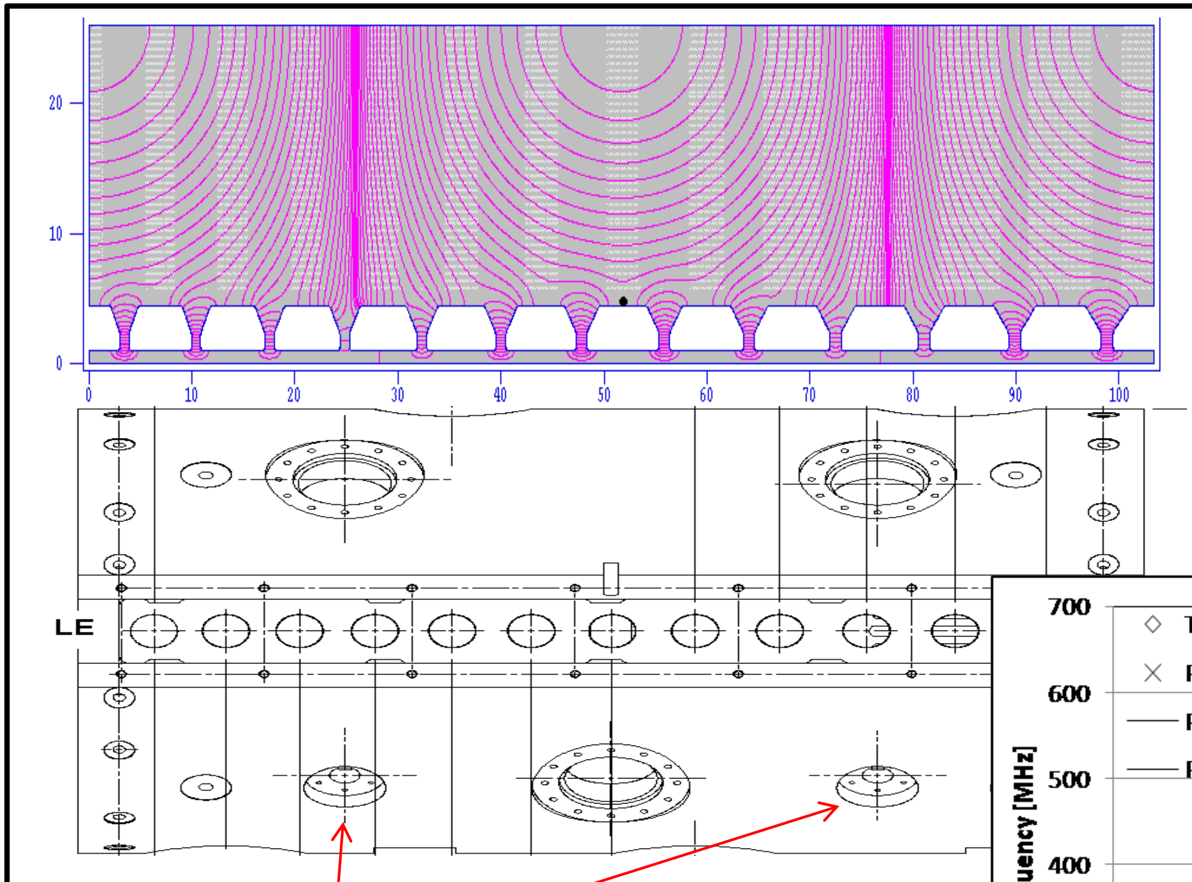
PC4 [mm]	PC3 [mm]	PC2 [mm]	PC1 [mm]
180	182	184	186



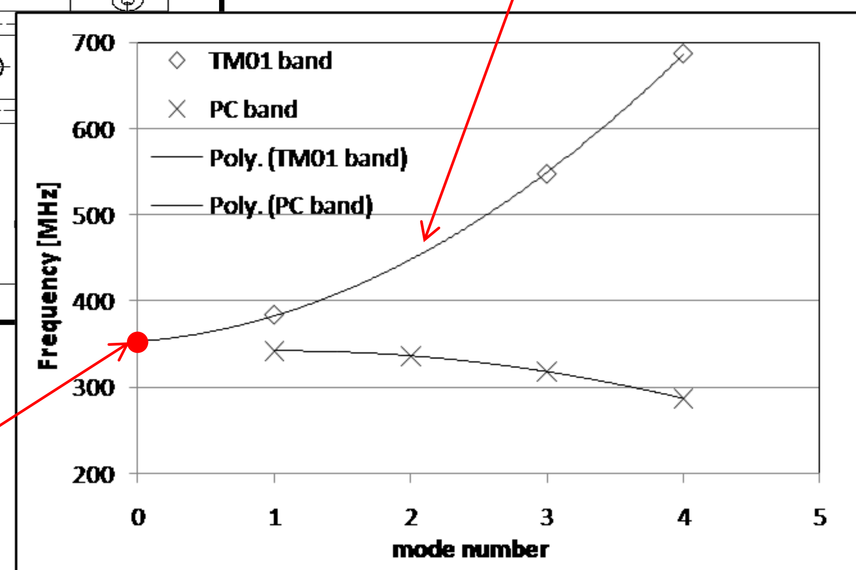




Measured prototype modes



TM_{012} is not excited because of the particular position of pick-ups on the cavity



Pick-ups

operating 0-mode

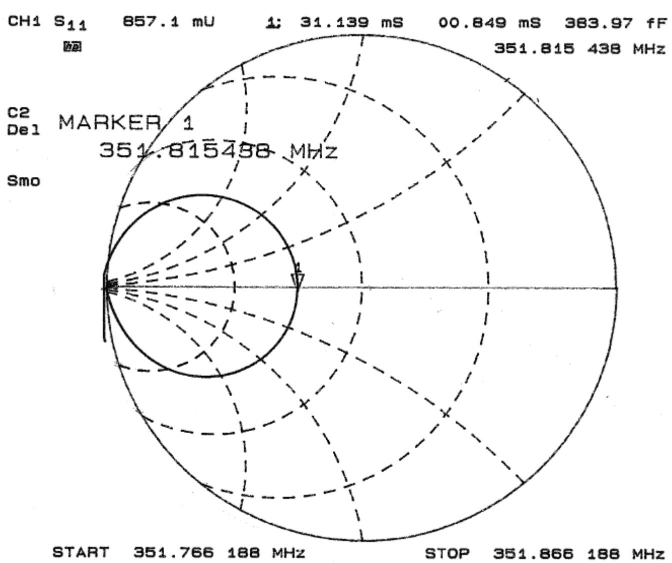
Prototype RF parameters

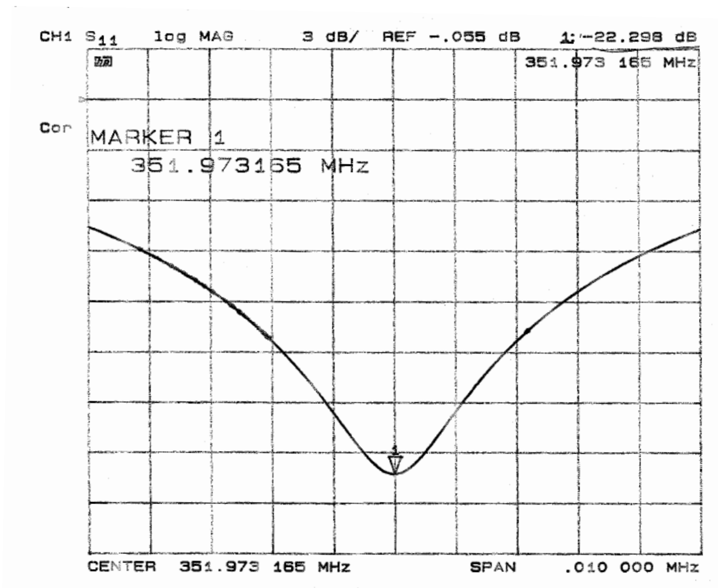
- Q_0 = 34200, about 80% of nominal value, simulated with Superfish
- Coupling strength β = 0.85, Q_L = 18500

$$SWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Under-coupling between waveguide and cavity

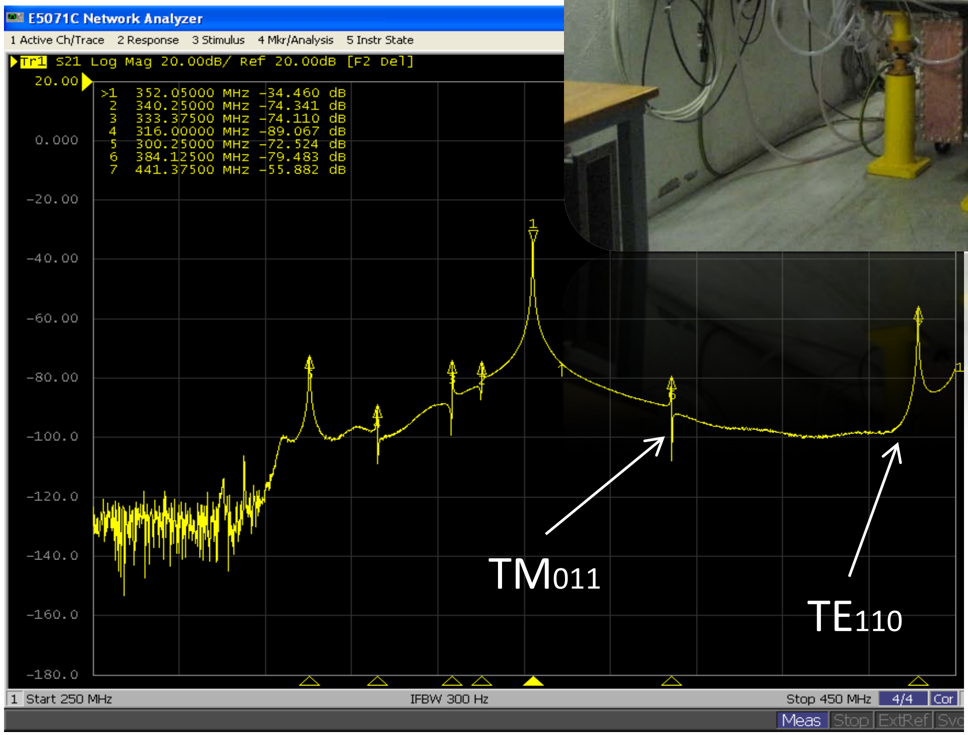
$$\beta = \frac{1}{SWR}$$





...towards high power test

- Port 1 on the waveguide
- Port 2 on the cavity
- N-WG2300 transition



Outline

- Low power measurements (structure and post-couplers modes, working frequency, Q_0, Q_L, β)
- High power measurements (cavity acceptance test, PMQ test)

High power tests

- Why
  - acceptance test
  - pre-conditioning prior to the cavity operation
- When
  - at the end of October 2009 (21-10-09) starts the conditioning of the Linac4 DTL prototype
- Where
  - SM18 area at CERN (2173-R-A39)

Main characteristics (1/2)

- The goal of this test phase was to achieve the nominal field level of 3.3 MV/m. Considering the quality factor of the cavity, a peak power of P_{cav} = 220 kW is required to achieve the designed field level.
- Linac4 duty cycle (0.08%) with a repetition rate of 2 Hz and a pulse width of 400 µs.
- The structure has also been tested at the maximum of 7.5% HP-SPL duty cycle (50 Hz, 1.5 ms).
- The power source is a LEP-type klystron (1 MW, CW). The klystron operates in dc power and the input signal is generated by a Rhode & Schwartz signal generator in the control room. The signal frequency and the input signal level are supplied to a pre-amplifier connected to the klystron.
- Pulse length and repetition rate are remotely controlled by LabVIEW software. The klystron cathode voltage is limited to -58 kV; the maximum applied current is 9.6 A, for a dc power of about 560 kW. As the klystron efficiency is estimated to be around 60%, maximum expected input power from the klystron should be $P_{+} \approx$ 330 kW.

Main characteristics (2/2)

- Limited circulator load: 300kW reflected power
- Directional coupler on the waveguide
- Vacuum window at roughly 1 meter form RF port
- Short circuit at almost $\lambda/4$ from the RF port
- Cavity: 2 pick-ups with RF detectors
- One vacuum pump
- Water flow meters
- Thermocouples
- RF detectors (CERN yellow box)
- **P**rogrammable **L**ogic **C**ontroller
- LabVIEW

Testing and conditioning procedure

- Low power to high power
- Short to long pulses
- Low to high repetition rate
- Limitation of power rise by hardware thresholds (vacuum, powers, water temperature)
- Vacuum and reflected power feedback loop to keep the SW interlocks far from the HW interlocks

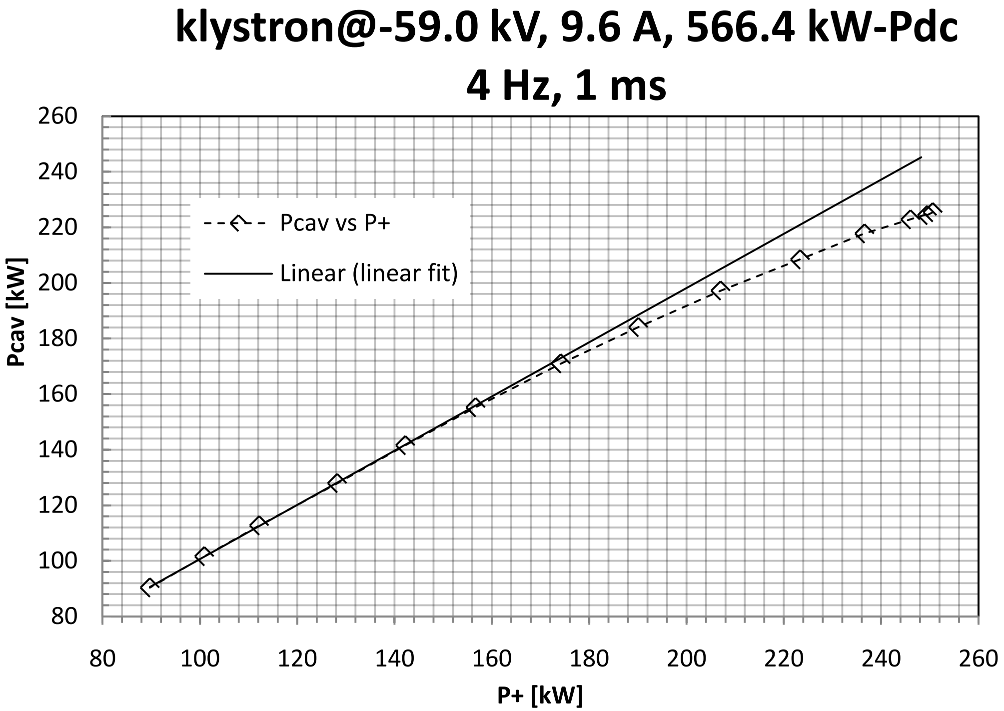
<u>HW interlocks</u>

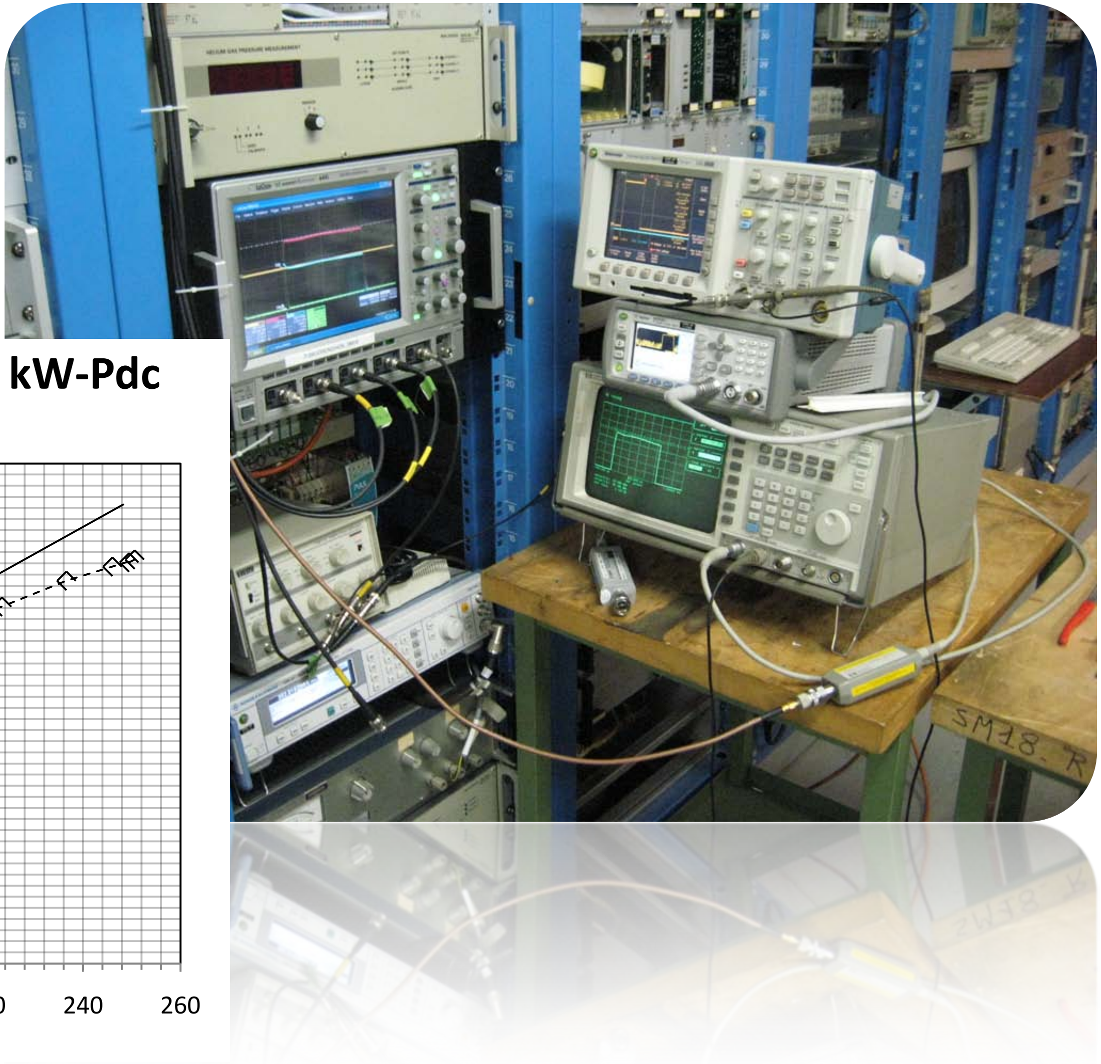
- temperatures on post-couplers, tuners, drift tubes, iris, end-cones, input water
- vacuum
- water flow
- forward, reverse, cavity powers

<u>SW interlocks</u>

- all the HW interlocks
- thresholds are tighter than HW interlocks in order to reduce RF-off time

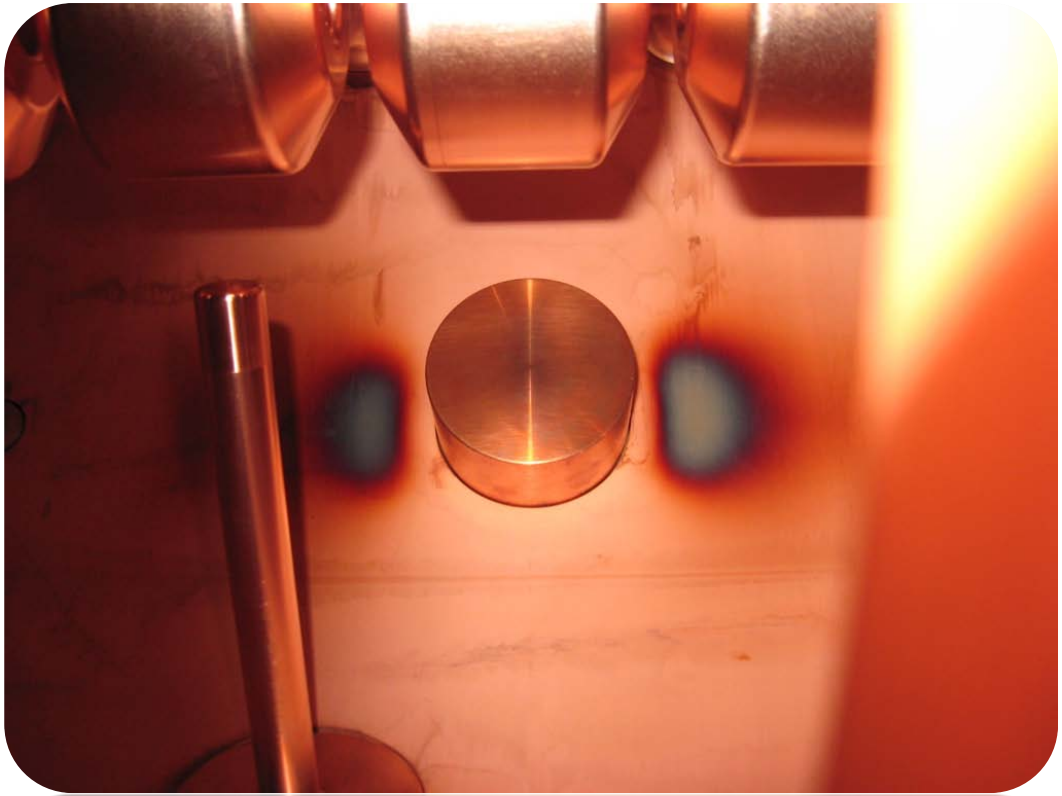
Measured powers





P_{cav} as a function of P_+ from klystron at different step of conditioning. P_- is zero

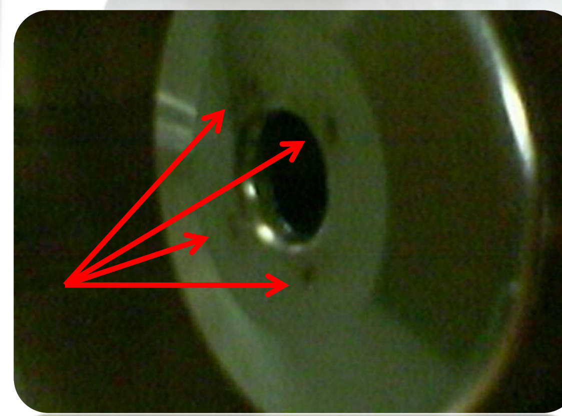
…after 1st high power test



- Reflected voltage monitored by the RF detector (green), cavity voltage (red), forward voltage (blue).
- The reflected voltage shows a saw-tooth pattern that indicates electron emission.
- This is due to the sharp edges of the tuners and interconnecting waveguide

PMQs high power tests

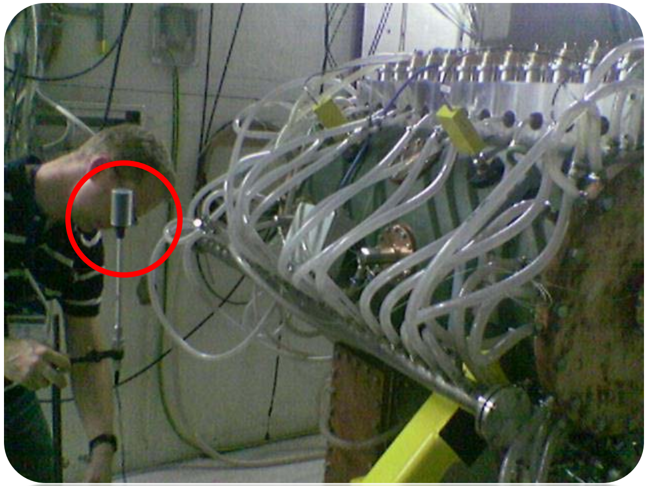
- 3% d.c. (20Hz, 1.5msec) and with different PMQs.
- During test some bursts on the reflected power have been observed.
- The periodic effect on the reflected power has always been observed.



These tests have shown that anodizing is not compatible with vacuum and so stainless steel or a titanium matrix shall be used.

X-rays measurements

- X rays emission was measured during the first phase of conditioning of the prototype.
- Their estimation is difficult without information of the X ray source such as geometry and material composition.
- The measurements have been performed on the side and on axis of the cavity with an ionization chamber PTW TM 23361, 30 cm^3 vented volume, S/N 429.
- The characteristics of the RF pulse were 50Hz repetition rate and 1.5msec pulse width.
- A 25Hz repetition rate was used in order to check the linearity of the emissions and so to validate the detector choice and the setup.
- In the second phase of conditioning (PMQs tests) these measurements were repeated at 20Hz repetition rate and 1.5msec pulse width.



X-rays measurements

Position	Peak Power [kW]	Repetition rate [Hz]	Hx(10) [Graetz] [μSv/h]	D[PTW] [μGy/h]	D[PTW] 2009 [μGy/h]	Ratio 2010/2009
Lateral	100	20	4	21	20	1.0
Lateral	120	20	22	74	80	0.9
Lateral	140	20	30	230	280	0.8
Lateral	160	20	61	480	880	0.5
Lateral	195	20	157	1300	3120	0.4
Lateral	203	20	170	1450	n.a.	n.a.
Longitudinal	100	20	4	340	680	0.5
Longitudinal	120	20	23	900	2380	0.4
Longitudinal	140	20	25	2500	6400	0.4
Longitudinal	160	20	133	5400	16800	0.3
Longitudinal	195	20	172	13000	60000	0.2
Longitudinal	203	20	180	17500	n.a.	n.a.
Longitudinal	220	20	275	25400	n.a.	n.a.

M. Widorski

Dose rates measured at different positions and operational conditions. The last but one column gives the values measured in 2009 for the same power and position (the values have been scaled for the lower repetition rate)