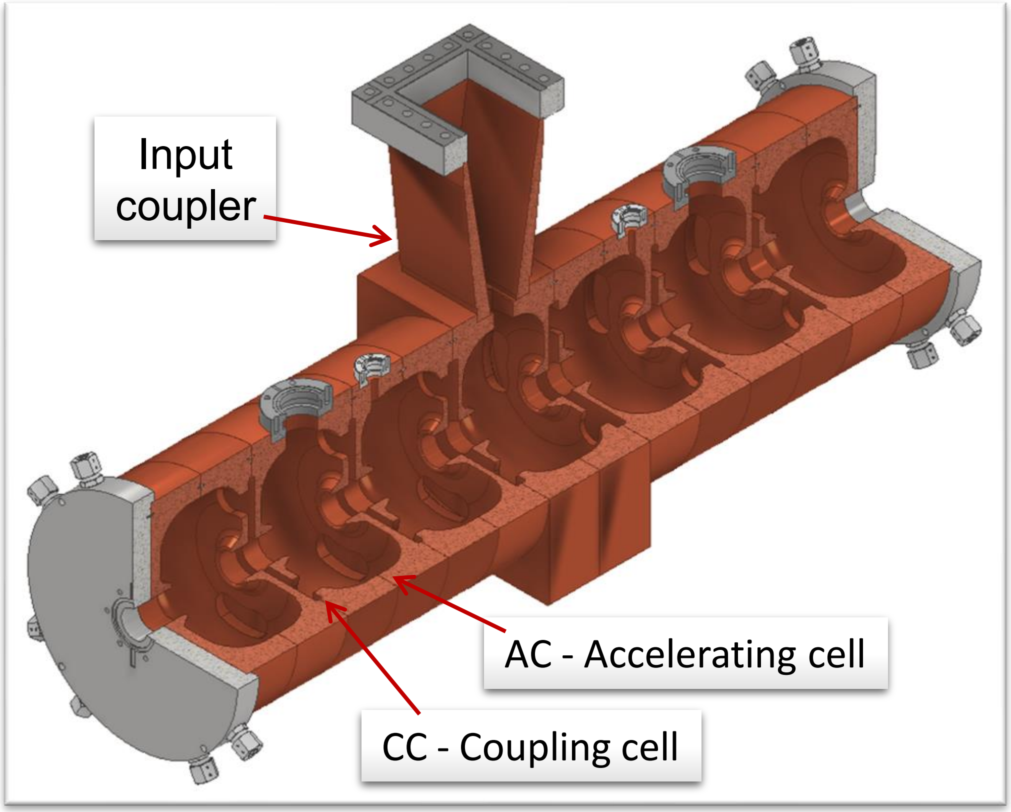
Testing of the Milliampere Booster Prototype Cavity

- The milliampere booster MAMBO is the pre-accelerator for the Mainz Energy-recovering Superconducting Accelerator MESA [1-4, 7, 8, 11]. (MESA film)
- MAMBO uses a 1.3 GHz normal conducting bi-periodic $\pi/2$ RF-structure for higher acceleration efficiency [5, 6].
- MAMBO accelerates electrons from 100 keV to 5 MeV. It uses four RF-sections. A graded-β and three constant-β [9, 10, 12].
- The graded-β sections needs to be equipped with solenoids for focussing the low energy beam [13].
- Simulation showed multipactor in CC with B_{sol}, thus length of CC was increased and accelerating field reduced to E_{acc}= 0.66 MV/m [14].

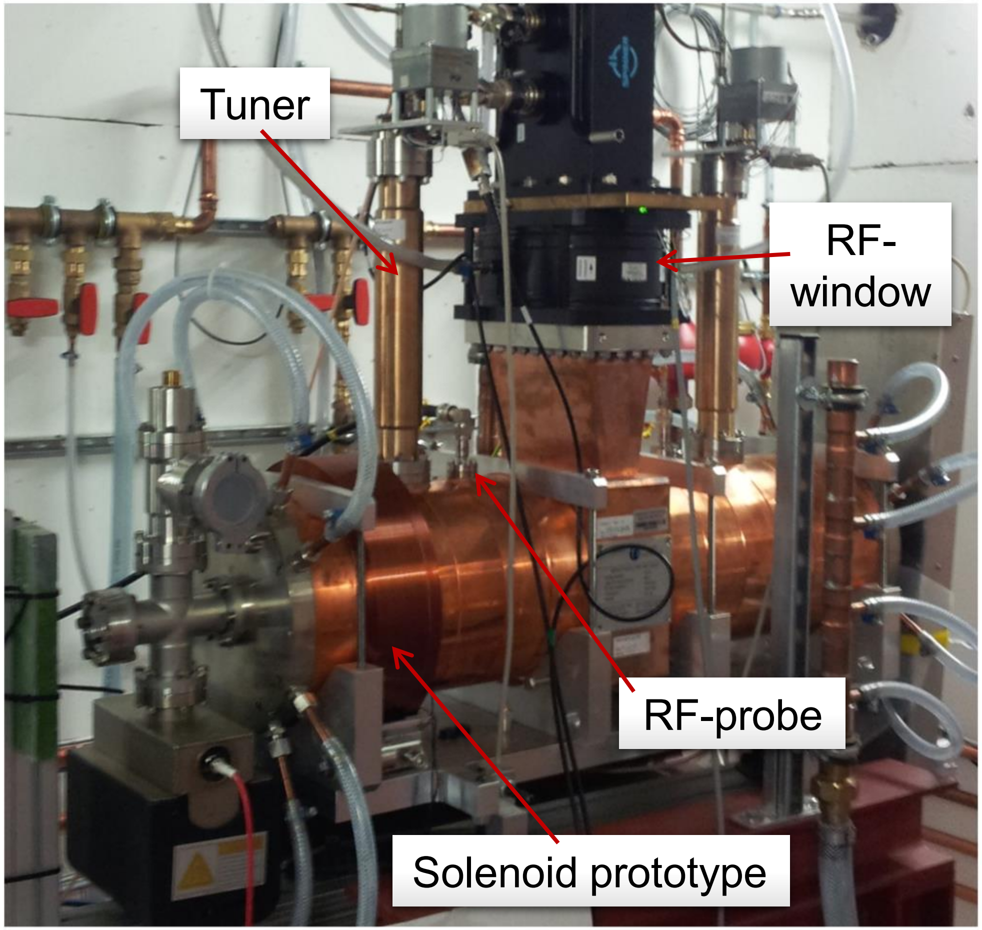


Technical drawing of the MAMBO prototype cavity.

Testing of the Milliampere Booster Prototype Cavity

- The prototype was designed to reach E_{acc}≈1MV/m with a 15kW solid-state power amplifier available [16]. That is well above the nominal gradient, so any operational limitation should become evident (e.g. multipactor).

AC:CC	7:6		CST	Exp.
f_0 (MHz)	1300	Q_0	23500	20938 ±503
L_{eff} (mm)	807.1	R_S (MΩ)	42.8	37.7 ±0.5
R/Q (kΩ)	1.8	κ	1	0.94



MAMBO prototype cavity at the test bunker of the Helmholtz Institute Mainz [17].

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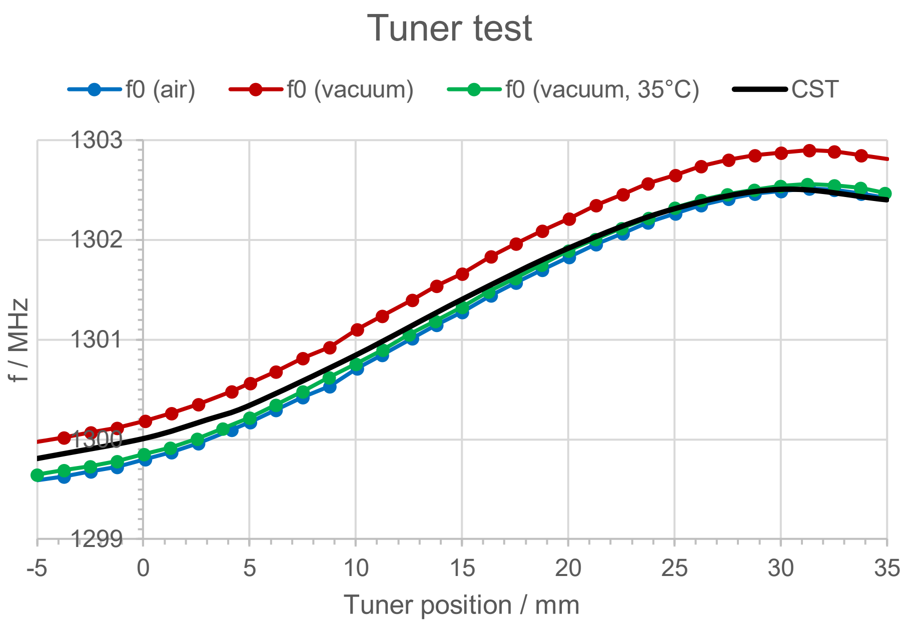
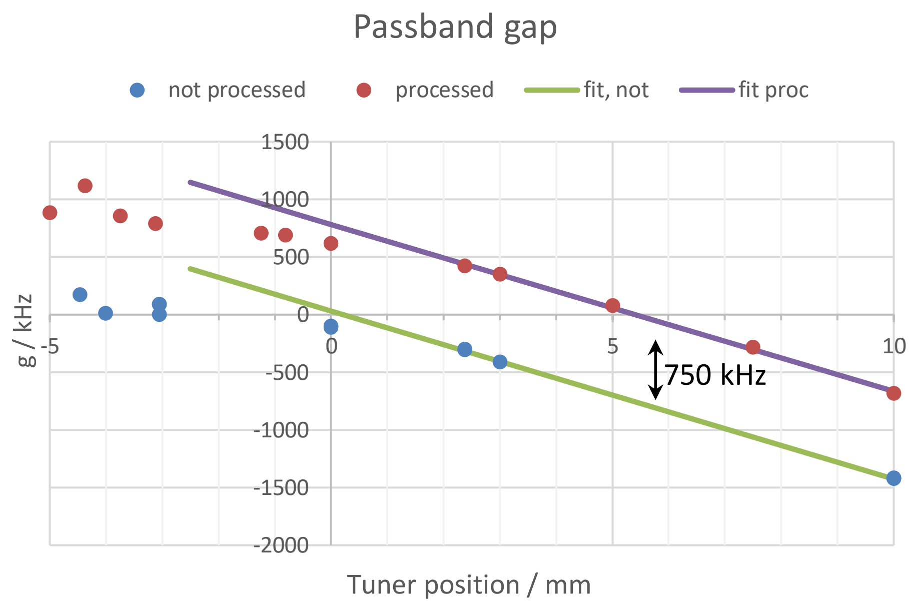
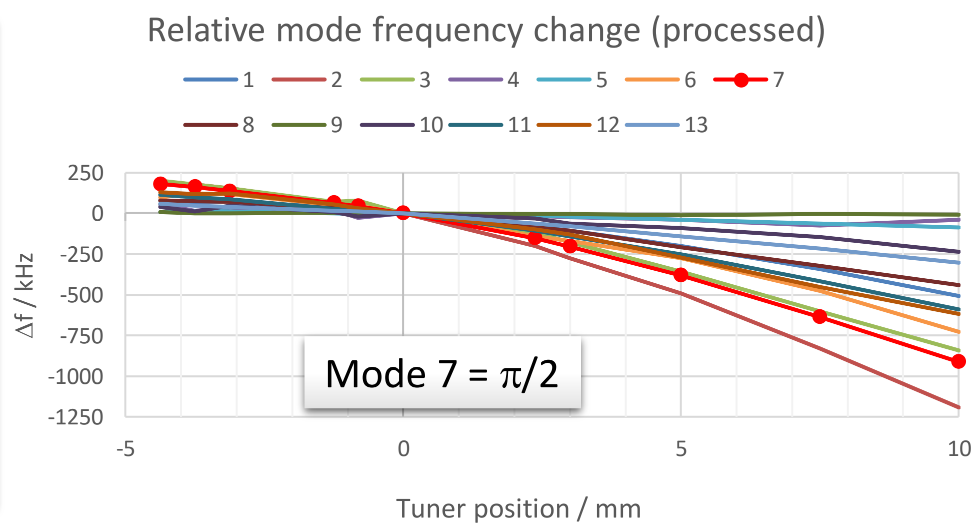




Low power testing:

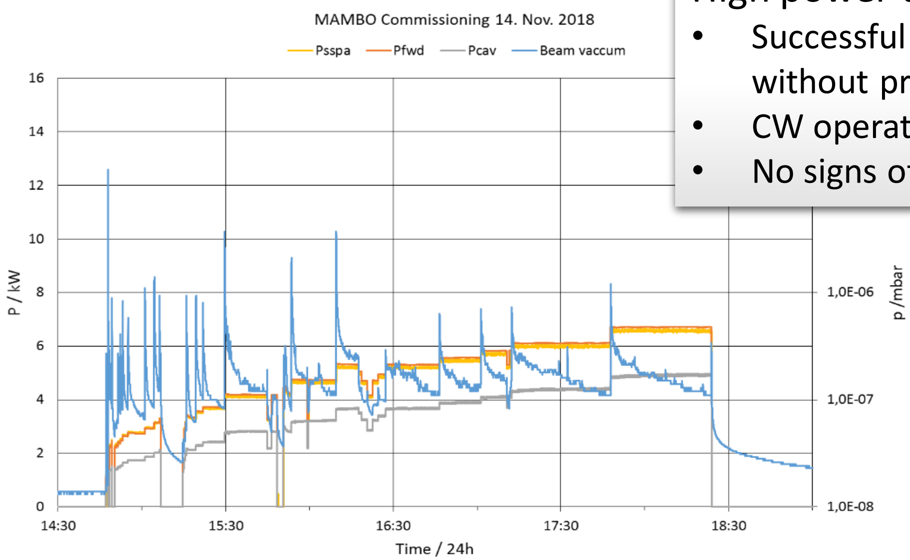
- Tuner range is in good agreement with theory.
- Passband gap *g* changes with tuner position, because each mode shifts differently.
- heated to 65°C for 14 days before processing.
- Permanent change of passband gap after high power test ≈750 kHz.

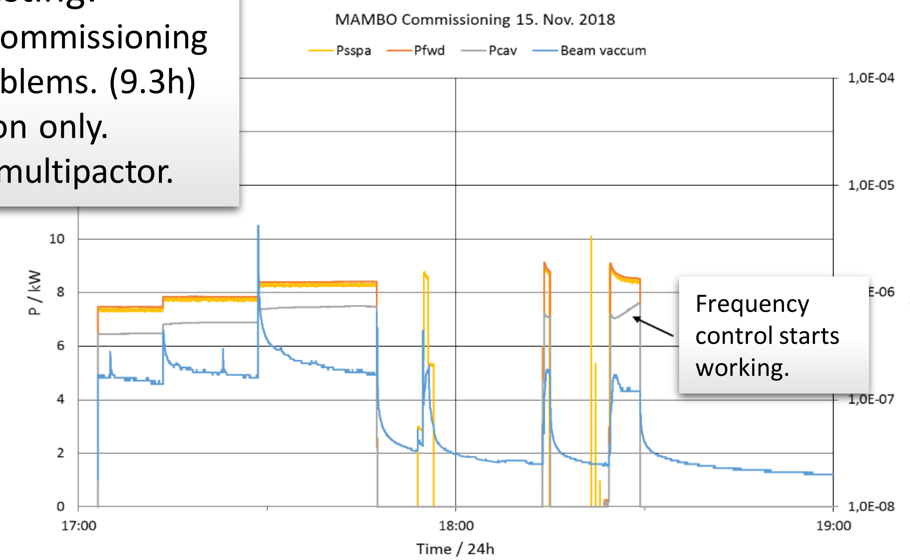


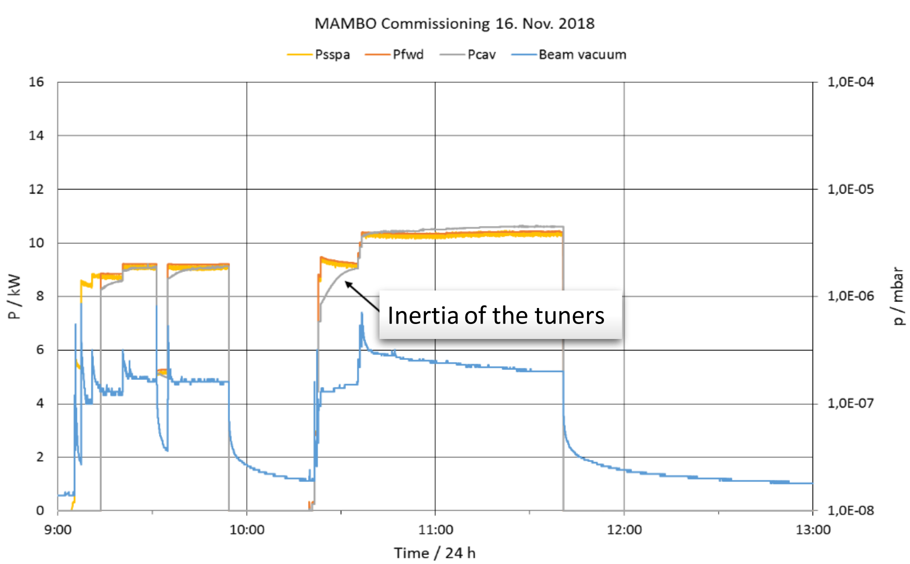
Testing of the Milliampere Booster Prototype Cavity

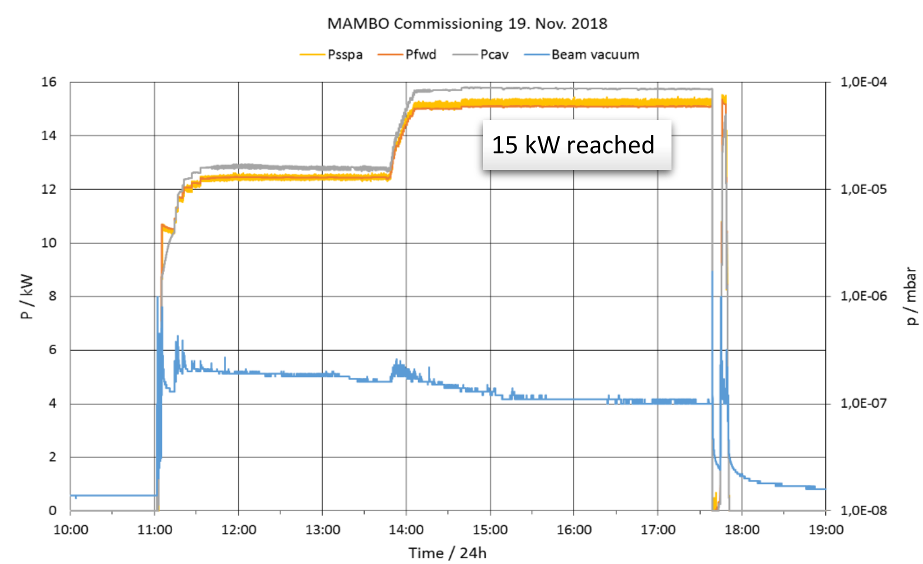
High power testing:

- Successful commissioning without problems. (9.3h)
- CW operation only.
- No signs of multipactor.

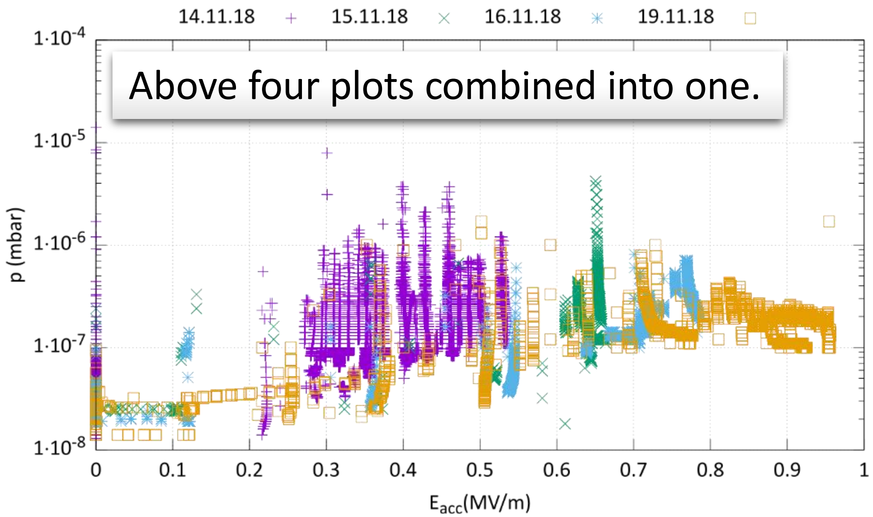


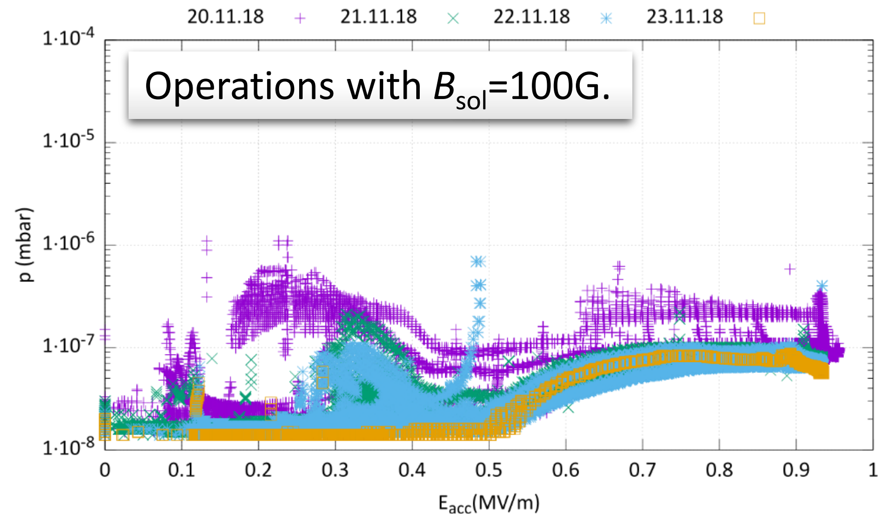


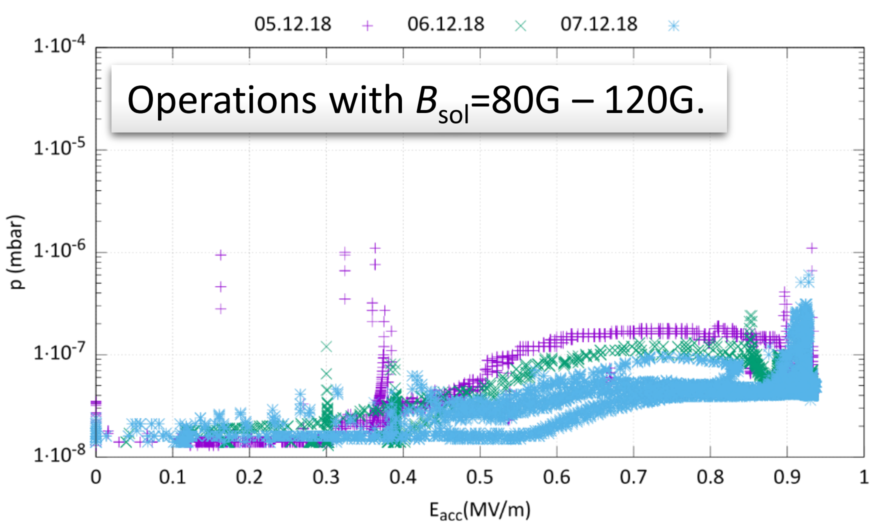




Testing of the Milliampere Booster Prototype Cavity





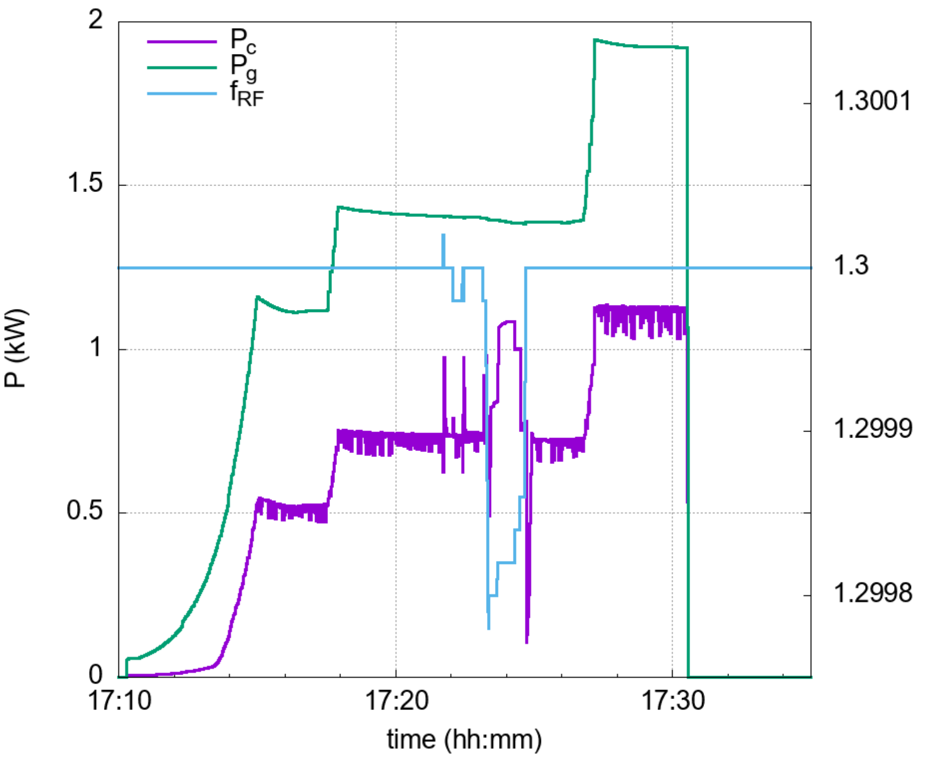


More information if one looks at pressure as a function of field $p(E_{acc})$:

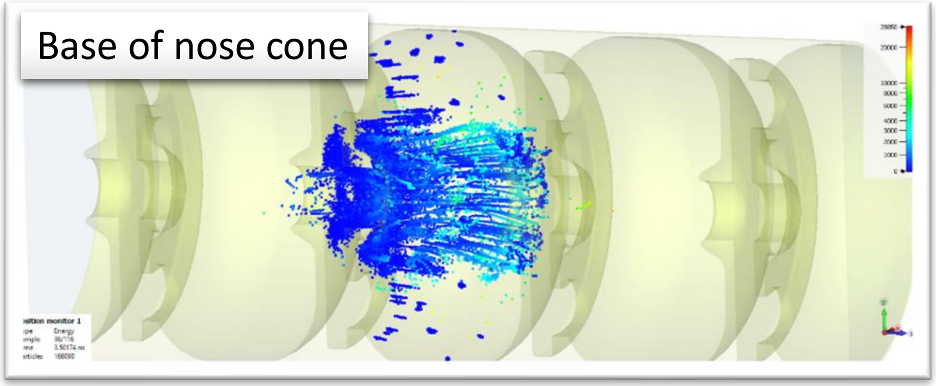
- There are some vacuum activities at $E_{acc} \approx [0.2, 0.4]$ MV/m with B_{sol} switched on that vanished after some power ramping. So this could not be investigated.
- Pressure rises for $E_{acc} > 0.5$MV/m. Pressure level decreases with operation time.

Testing of the Milliampere Booster Prototype Cavity

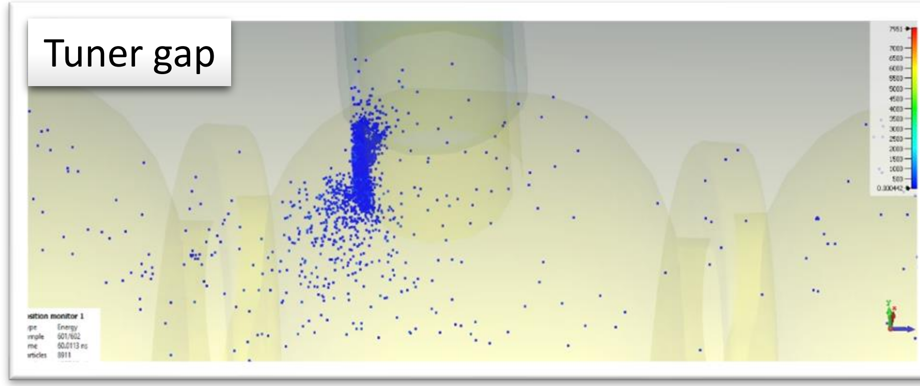
- After venting in Aug. 2019, some power fluctuations in the cavity were found at low field (P_c<2kW, E_{acc}< 0.3MV/m) during reprocessing. (→ no problem for standard operation)
- Fluctuations independent of B_{sol}.
- Fluctuations stop by changing frequency. → Possibly multipactor?
- Maybe some pollution during venting? Cavity was not heat treated before reprocessing. → Mandatory for the future?
- Multipactor simulations revisited.



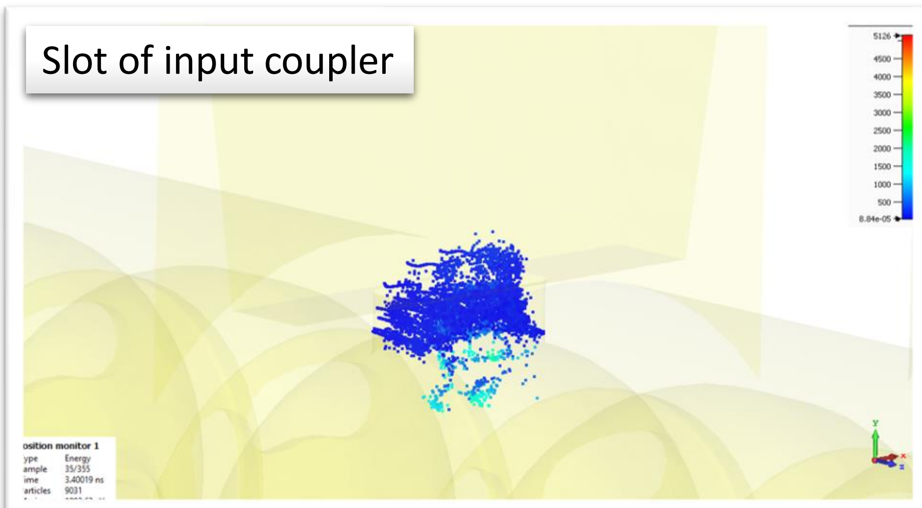
Testing of the Milliampere Booster Prototype Cavity



Found with B_{sol} at E_{acc} > 0.2MV/m.



Found with B_{sol} at E_{acc} > 0.3MV/m and without B_{sol} at E_{acc} > 0.4MV/m.



Always found at E_{acc} > 0.7MV/m.

- The three above locations with tendency for multipactor were found.
- Threshold behaviour of the fluctuations could not be reproduced with simulation. The origin of the effect is still unclear.
- Multipactor found at nose cones might be the cause for processable vacuum activity at $E_{acc} \approx [0.2, 0.4]$ MV/m.
- Multipactor in tuner gap might explain pressure rise at E_{acc}> 0.5MV/m.

References:

[1] F. Hug et al. “Status of the MESA ERL-Project”, ERL’19, Berlin, Germany, Sept. 2019, MOCOXBS05, p. 14. doi:10.18429/JACoW-ERL2019-MOCOXBS05

[2] J. Teichert et al. “RF Status of Superconducting Module Development Suitable for CW Operation: ELBE Cryostats”, Nucl. Instr. Meth. A 557, 239 (2006). doi:10.1016/j.nima.2005.10.077

[3] T. Stengler et al. “Modified ELBE Type Cryomodules for the Mainz Energy-recovering Superconducting Accelerator MESA”, SRF’15, Whistler, BC, Canada, Sept. 2015, THPB116, p. 1413, http://accelconf.web.cern.ch/SRF2015/papers/thpb116.pdf.

[4] T. Stengler et al. “Status of the superconducting cryomodules and cryogenic system for the Mainz Energy-recovering Superconducting Accelerator MESA”, IPAC’16, Busan, Korea, May 2016, WEPMB009, p. 2134, http://accelconf.web.cern.ch/ipac2016/papers/wepmb009.pdf.

[5] D.E. Nagle, E.A. Knapp, B.C. Knapp. “Coupled Resonator Model for Standing Wave Accelerator Tanks”, Rev. Sci. Instrum. 38, 1583 (1967). doi:10.1063/1.1720608

[6] E.A. Knapp, B.C. Knapp and J.M. Potter, “Standing Wave High Energy Linear Accelerator Structures”, Rev. Sci. Instrum. 39, 979 (1968). doi:10.1063/1.1683583

[7] D. Becker et al. “The P2 Experiment”, Eur. Phys. J. A 54, 208 (2018). doi:10.1140/epja/i2018-12611-6

[8] S. Baunack. “Low Energy Accelerators for High Precision Measurements”, Electromagnetic Interactions with Nucleons and Nuclei Conference (EINN20017), Paphos, Cyprus, Oct. 2017, http://einnconference.org/2017/presentations/01_Nov/W2/Baunack.pdf.

[9] R. Heine, K. Aulenbacher. “Injector Linac for the MESA Facility”, IPAC’13, Shanghai, China, May 2013, WEPWA001, p. 2150, http://accelconf.web.cern.ch/IPAC2013/papers/wepwa011.pdf.

[10] H. Euteneuer et al. “The Injector Linac for the Mainz Microtron”, EPAC88, Rome, Italy, June 1988, p. 550, http://accelconf.web.cern.ch/e88/PDF/ EPAC1988_0550.PDF.

[11] B. Aune et al. “Superconducting TESLA Cavities”, Phys. Rev. ST-A/B **3**, 092001 (2000). doi:10.1103/PhysRevSTAB.3.092001

[12] R. Heine. “Preaccelerator concepts for an energy-recovering superconducting accelerator”, Phys.Rev.Accel.Beams **24**, 011602 (2021). doi:10.1103/PhysRevAccelBeams.24.011602

[13] R. Heine et al. “Further Investigations on the MESA Injec tor”, IPAC’15, Richmond, VA, USA, May 2015, TUPWA045, p. 1515. doi:10.18429/JACoW-IPAC2015-TUPWA045

[14] R. Heine et al. “Current Status of the Milliampere Booster for the Mainz Energy-recovering Superconducting Accelerator”, IPAC’16, Busan, Korea, May 2016, TUPOW002, p. 1741, http://accelconf.web.cern.ch/ipac2016/papers/tupow002.pdf.

[15] T.P. Wangler. “RF Linear Accelerators”, Wiley-VCH, 2nd edition, 2007. doi:10.1002/9783527623426

[16] R. Heine, F. Fichtner. “The MESA 15kW CW 1.3 GHz Solid State Power Amplifier Prototype”, IPAC’18, Vancouver, BC, Canada, May 2018, THPMF063, p. 4216, http://accelconf.web.cern.ch/ipac2017/papers/thpik023.pdf.

[17] F. Hug et al. “Cryogenic Installations for Module Tests at Mainz”, SRF2019, Dresden, Germany, 30. June - 5. July 2019, THP054, p. 999. doi:10.18429/JACoW-SRF2019-THP054