Single Mode Structures as an Alternative for the PETRA IV High Harmonics RF System

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DESY, Hamburg, 08.11.2021

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

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Motivation for searching a single mode structure

- HH-rf-system needs a frequency of 1.5GHz, the 500MHz BESSY-HOM-damped cavity was downsized by a factor of 3.
- simply downsizing is mechanically not an easy task
- longitudinal loss factor $k_l \sim f$
- transversal loss factor $k_\perp \sim f^2$
- increased HOM damping capabilities for the HH-rf-system would be desireable!

- Driven by the arguments we have started to look for other cavity concepts which have to fulfil the following requirements:

1) The concept has to be mechanically very simple
2) The HOM-damping capabilities must be more effective compared to the BESSY-cavity

What is a sigle mode structure

The basic idea of a “single mode structure”

- Accelerating structures are usually designed in such a way that it is possible to excite a field formation with a rf-source which is suited to accelerate charged particles.
- But other field formations with higher frequencies could be excited
- This field formations are able to perturb the acceleration process, to deteriorate the beam quality and in the worst case they lead to a beam blow up
- The single mode accelerating structure is designed in such a way that all modes, except the wanted mode, will leave the cavity through a coupling hole into the direction of an rf-absorber
- If this can be managed one has a “single mode Structure” (the name was created, as far as I know, by M. Tigner [1])

First Proposal of a “single mode structure”

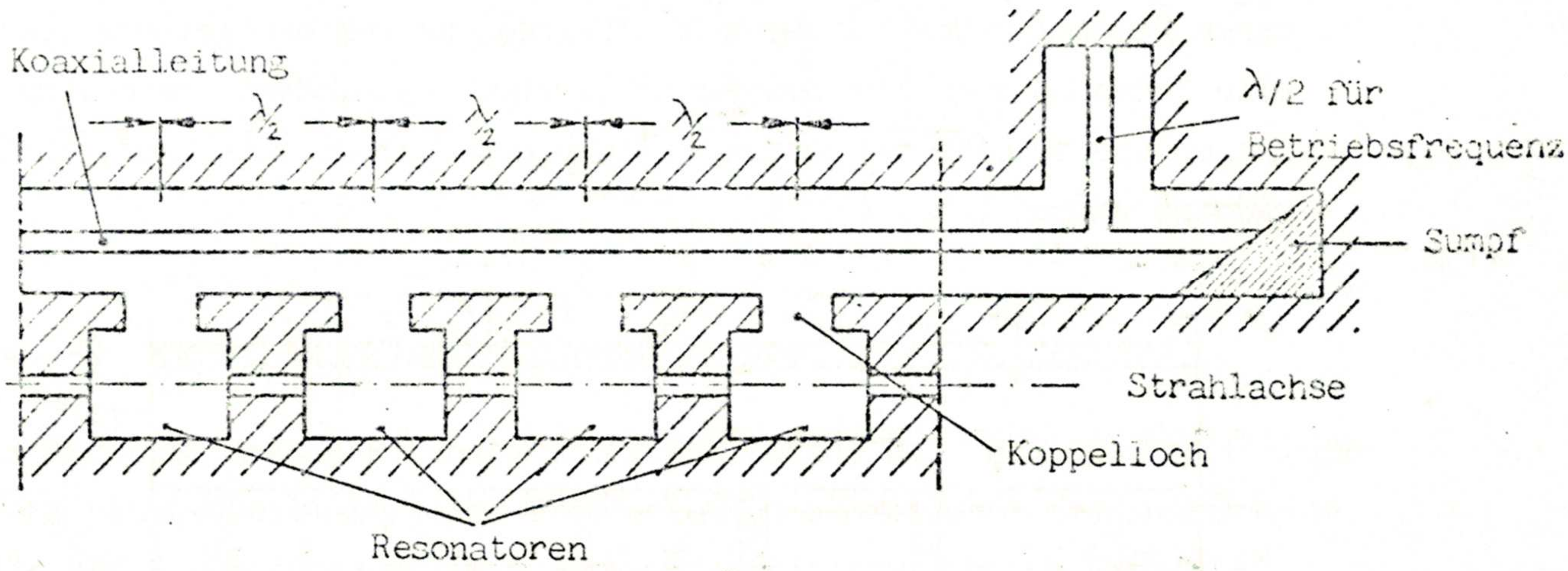

Fig. 1: *One of the first proposals of a so called “single mode structure” [1]*

Picture: R. Klein: “Messung der Shuntimpedanz und Feldassymmetrie von Beschleunigerresonatoren, Diploma Thesis, Institut für Kernphysik der Johannes Gutenberg Universität Mainz, 1981, KPH 21/81

Two promising candidates for a closer look

The choke mode cavity created by Tsumoru Shintake

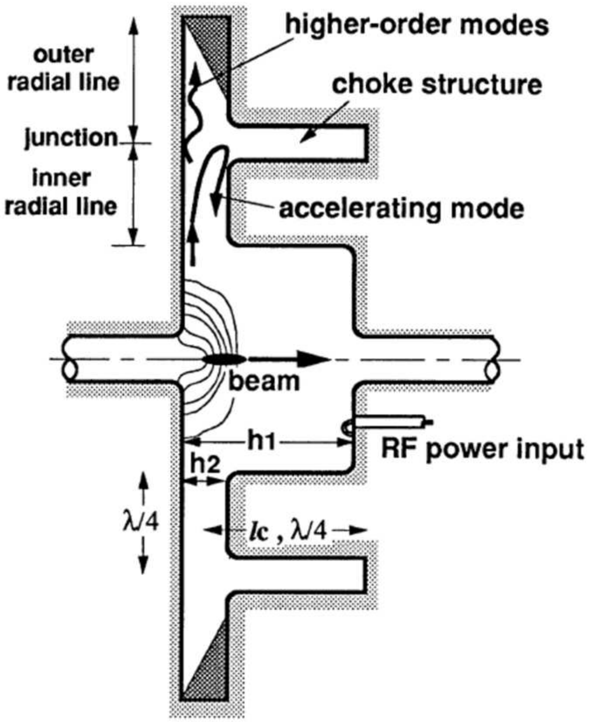

Fig. 2: *A cut view through the "choke mode cavity". The cavity is azimuthally symmetric. (Picture: T. Shintake [2])*

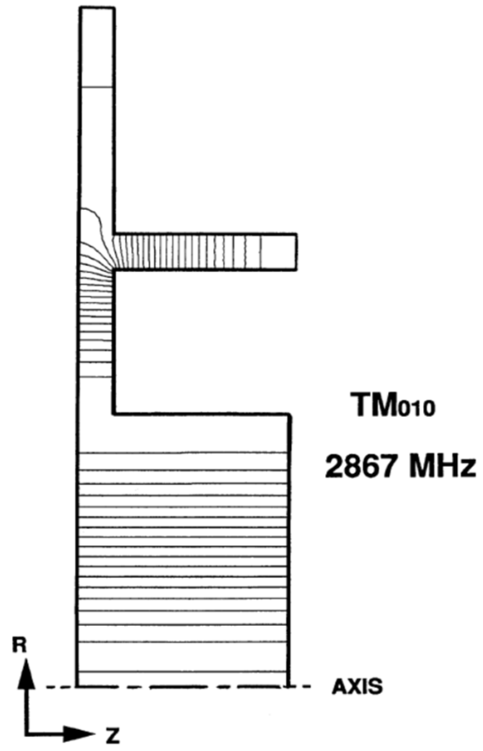

Fig. 3: *TM_{010}-Mode is rejected by the choke. Due to the distance of $\lambda/2$ from the short of the choke to the annular exit of the cavity, the TM_{010}-Mode "sees" a short. (Picture: T. Shintake [2])*

Two promising candidates for a closer look

The choke mode cavity created by Tsumoru Shintake

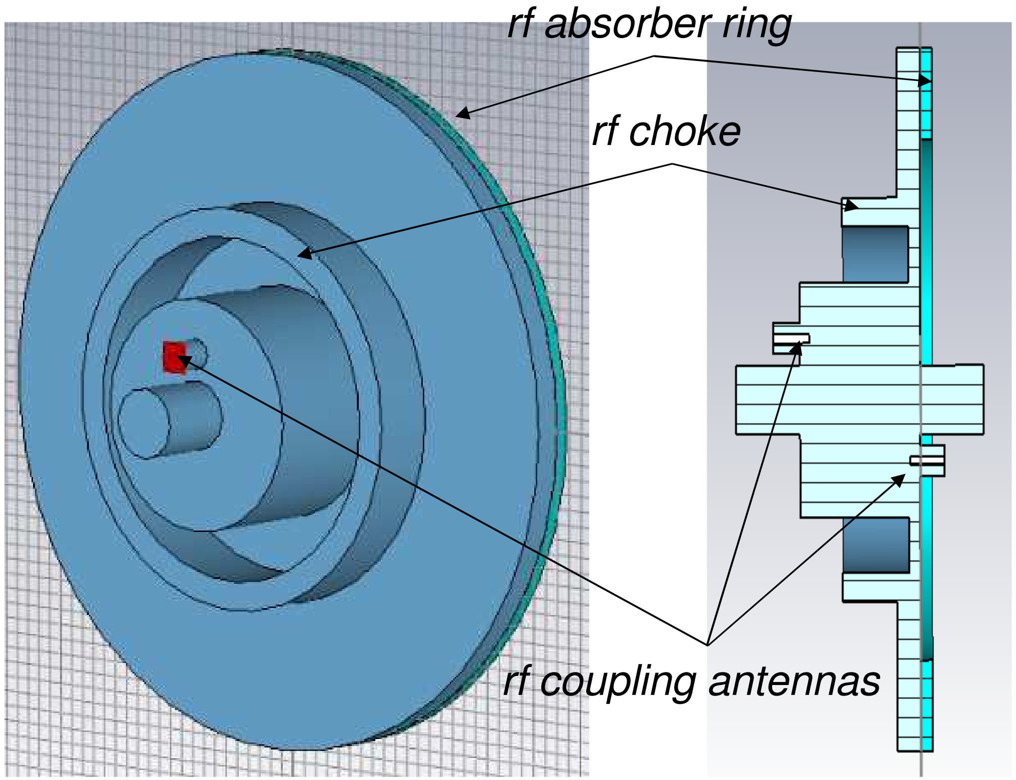

Fig. 4: *The enlarged (by a factor of 1,9 compared to T. Shintake [2]) model of the choke mode cavity in CST-MWS*

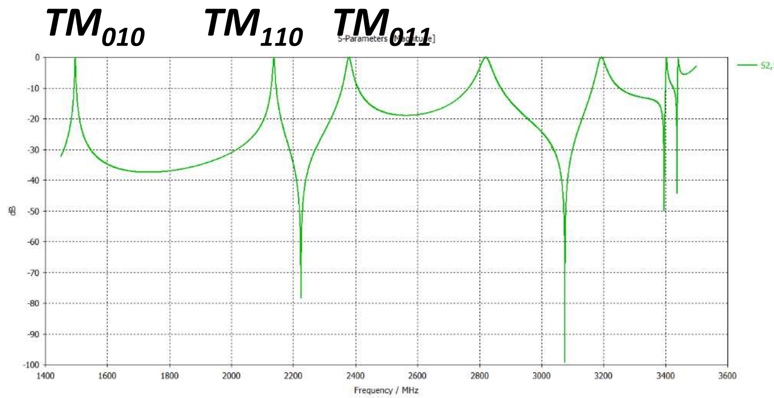

Fig. 5: *The TM-modes in the equivalent pillbox without the annular slot*

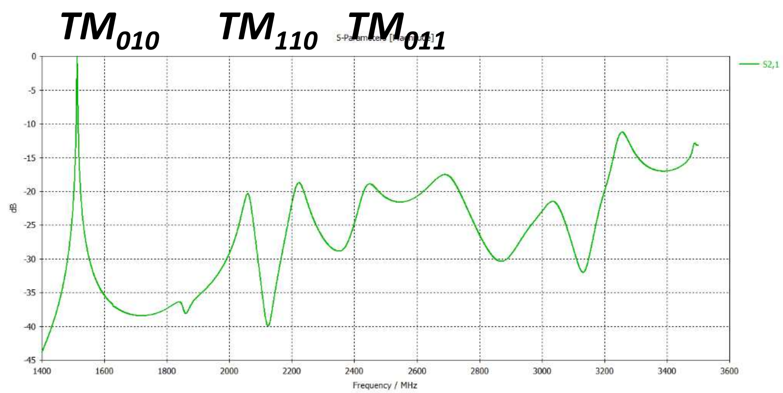

Fig. 6: *The TM-modes in the choke mode cavity*

Two promising candidates for a closer look

The choke mode cavity created by Tsumoru Shintake

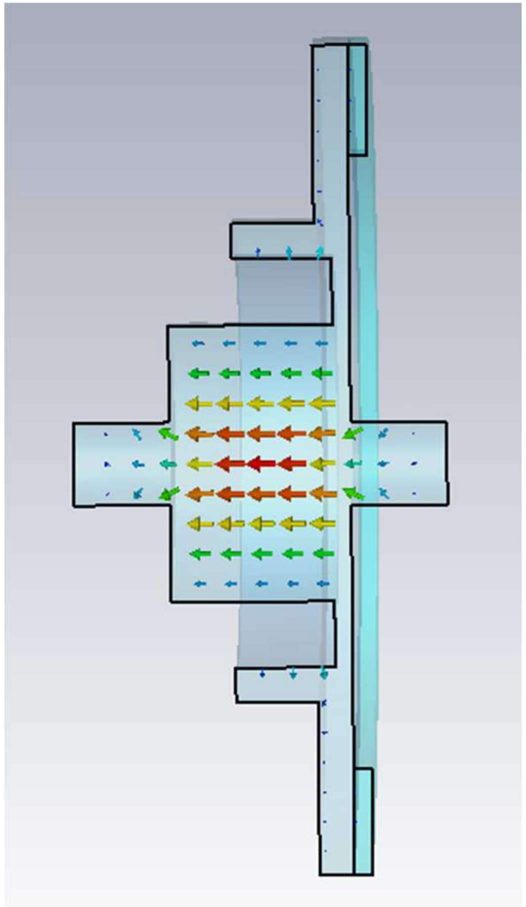

Fig. 5: *The TM010-mode in the choke mode cavity*

frequency	f_0	1,511GHz
shunt impedance (CST)	R_S	625kΩ
unloaded quality factor	Q_0	3090
	R_S/Q_0	202Ω

Table 1: *The characteristic numbers of the TM_{010}-mode in the choke mode cavity*

frequency	f_0	1,5GHz
shunt impedance (CST)	R_S	1,5MΩ
unloaded quality factor	Q_0	17.000
	R_S/Q_0	88Ω

Table 2: *The characteristic numbers of the TM_{010}-mode in the 1,5GHz BESSY-HOM-damped cavity*

Two promising candidates for a closer look

The TE_{11}-cavity created by Helmut Herminghaus at University of Mainz

The basic idea of H. Herminghaus

- Assume a circular waveguide in which a TE_{11}-wave is running
- It is possible to form a resonator by denting locally the circular waveguide
- The dents form a capacitive load and the cut-off frequency is locally decreased.
- By a suitable forming one is able to achieve a situation, where all modes, except the one with the lowest frequency, will be above the cut-off frequency of the tube and therefore they will run in a load at one end of the tube

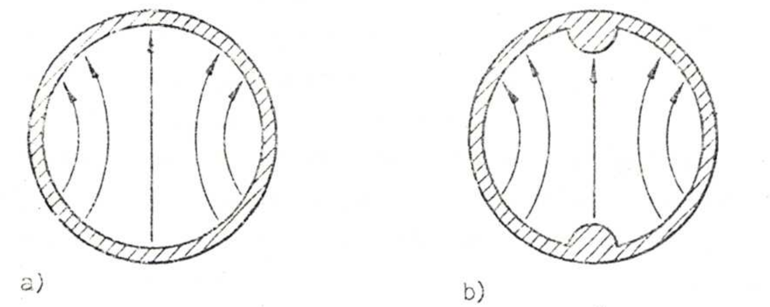

Fig. 6: *TE11-mode in a circular waveguide without and with dents [3]*

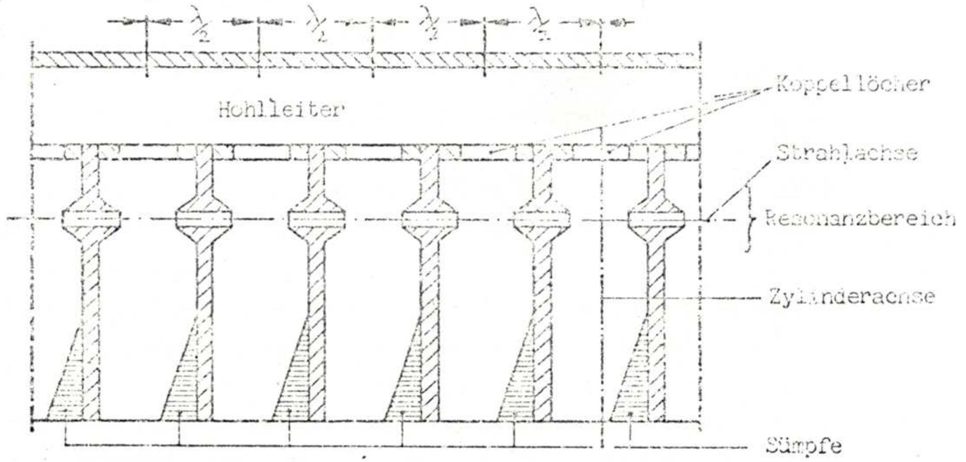

Fig. 7: TE11-single mode cavities connected to a rf feeder line. The dents are formed by the nose cones [3]

Two promising candidates for a closer look

A copper model of the TE_{11}-cavity created by Helmut Herminghaus at University of Mainz in 1978 for llrf-measurements. The model was provided by the courtesy of Prof. Dr. K. Aulenbacher and Dr. R. Heine (Institut für Kernphysik der Johannes Gutenberg Universität Mainz)

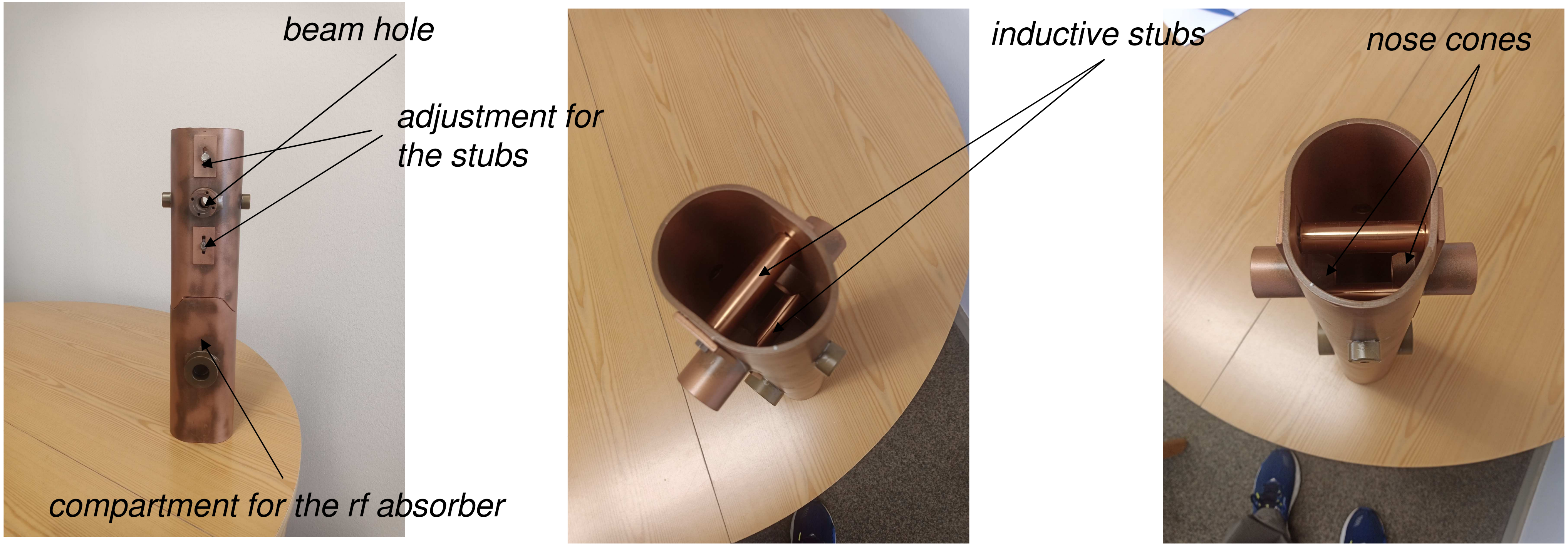

Fig. 8, 9 and 10: *A model of the TE_{11}-cavity for a frequency of 2451,8MHz. The upper part is the cavity itself, the lower part is for the . The picture in the middle or the right shows adjustable inductive stubs and the nose cones of the acceleration gap.*

Two promising candidates for a closer look

The TE_{11}-cavity created by H. Herminghaus

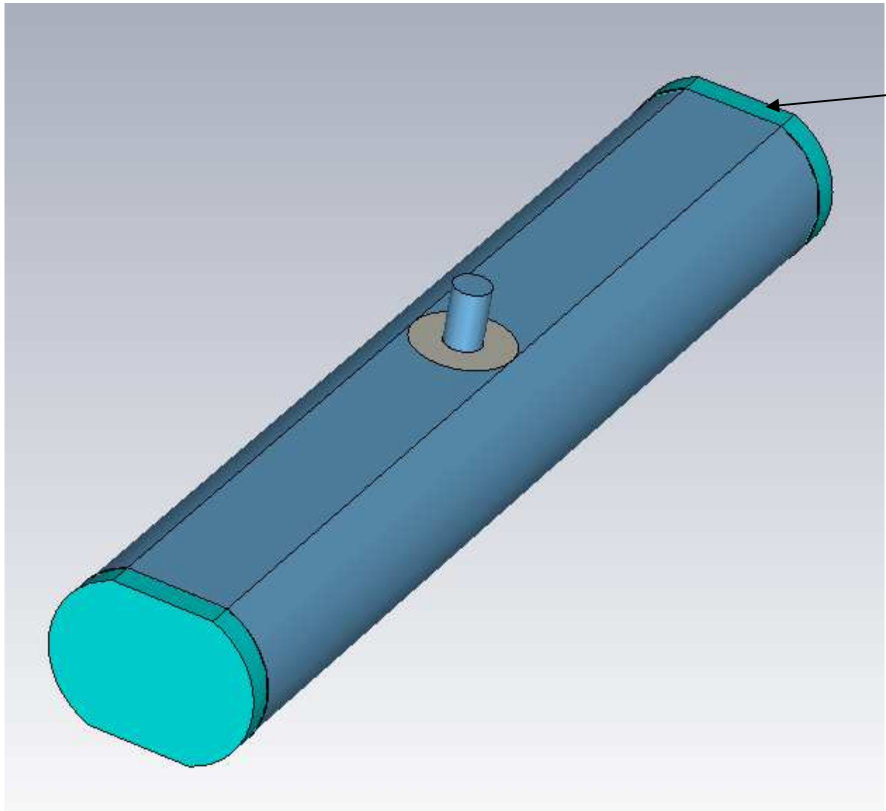

Fig. 11: *A simple model of the TE_{11}-cavity. At both ends the waveguide is terminated by lossy material*

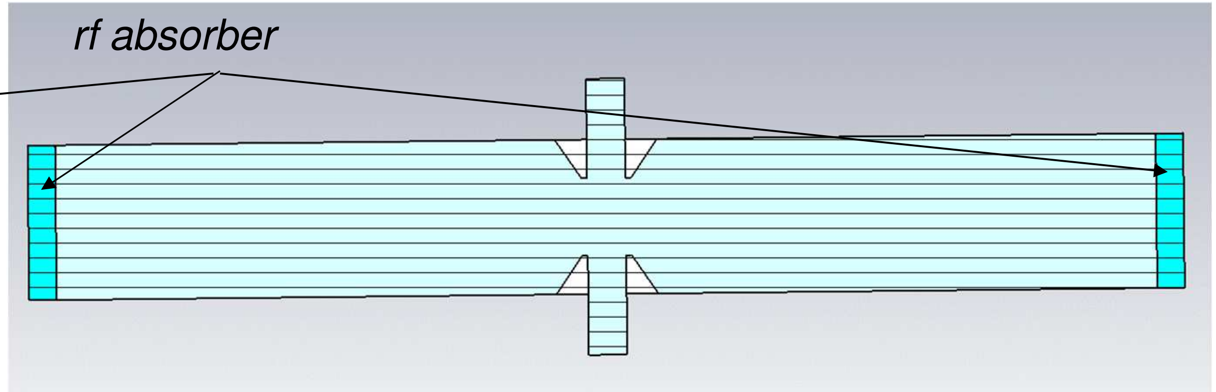

Fig. 12: *A cut through the TE_{11}-cavity shows the nose cones and the beam pipe*

- The dimensions were taken from the measurement model
- The needed dents were formed nose cones
- Frequency was of minor interest

Two promising candidates for a closer look

The TE_{11}-cavity created by Helmut Herminghaus at University of Mainz

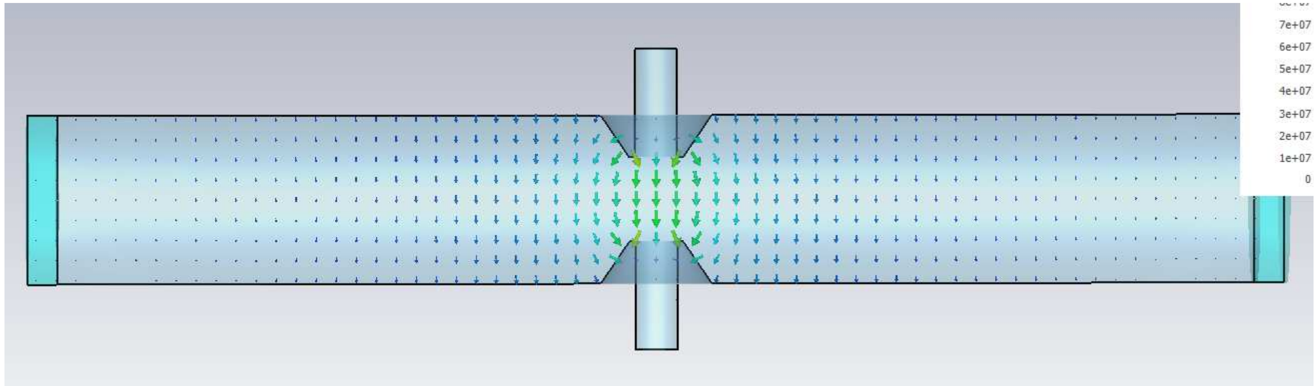

Fig. 13: *The trapped TE_{11}-acceleration mode between the nose cones. The mode is below cut-off to both sides of the gap and therefore a strong damping occurs*

frequency	f_0	2,104GHz
shunt impedance (CST)	R_S	1.1MΩ
unloaded quality factor	Q_0	11.200
	R_S/Q_0	183Ω

Table 3: *The characteristic numbers of the mode in Fig. 13.*

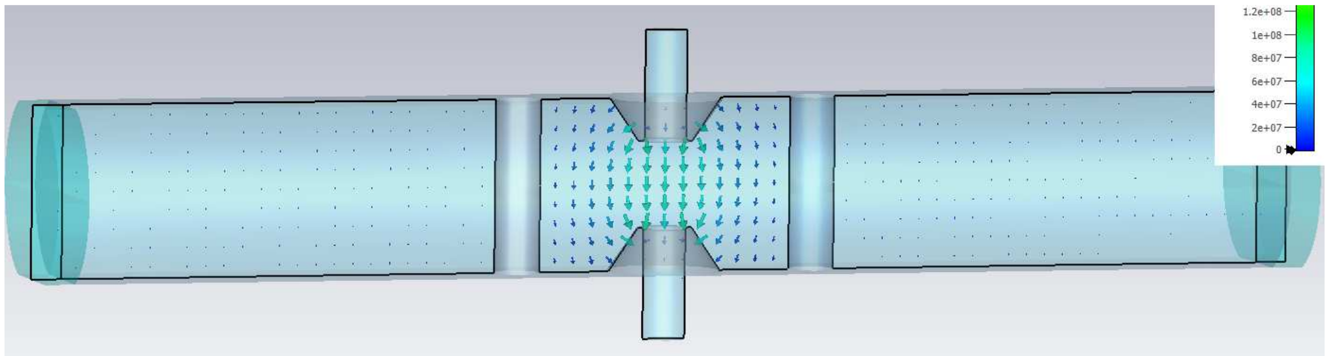

Fig. 14: *The TE_{11}-cavity is modified by the introduction of two inductive stubs. The stubs keep the field in the gap region and they enhance the characteristics by far.*

frequency	f_0	2,333GHz
shunt impedance (CST)	R_S	2,6MΩ
unloaded quality factor	Q_0	13.800
	R_S/Q_0	189Ω

Table 4: *The characteristic numbers of of the mode in Fig. 14*

Conclusion and outlook

Choke mode cavity

- Is azimuthally symmetric => easy to manufacture
- needs a high power ring coupler with waveguide connector (was already developed by T. Shintake)
- was already successfully tested concerning high-power- and vacuum capabilities by T. Shintake
- Has a lower shuntimpedance than the equivalent pillbox due to the additional losses by the choke

The TE_{111}-like cavity

- was not tested concerning the high-power and vacuum capabilities; a model structure exists only
- when optimized, the shuntimpedance is a factor of five higher than its pillbox equivalent
- easy coupling by a usual coupling loop from the top side seemed to be possible
- The field configuration is asymmetric and one has to find out how to arrange the cavities in the beam line to prevent problems from the viewpoint of particle dynamics

Thank you

Literature

[1] R. M. Sundelin, J. L. Kirchgessner, and M. Tigner, “Parallel Coupled Structure,” IEEE Trans. on Nuc. Science, Vol. NS-24, No.3, June 1977, pp.1686-1688

[2] Tsumoru Shintake: „ The Choke Mode Cavity“, 1992 Jpn. J. Appl. Phys. **31** L1567

[3] R. Klein: “Messung der Shuntimpedanz und Feldassymmetrie von Beschleunigerresonatoren, Diploma Thesis, Institut für Kernphysik der Johannes Gutenberg Universität Mainz, 1981, KPH 21/81

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