Particularities of normal conducting L-band deflecting cavities

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General remarks

1. *In S-band frequency range Normal Conducting (NC) structures operating both in Traveling Wave (TW) [SLAC, CERN] and in Standing Wave [SPARC] mode are known. Structure base is Disk Loaded Waveguide (DLW).*
2. *For NC structures the L-band frequency range is near the border between TW and SW mode of operation, (in the domain of SW influence).*

TW operation requires too much RF power. $\frac{E_0\lambda}{\sqrt{P}} = inv(f) = A_0, \quad P = (\frac{E_0\lambda}{A_0})^2 \sim \frac{1}{f^2}$

2. *SW operation – multi cell structure with operating π-mode for RF efficiency.*

SW operation, efficiency vs. stability (DLW)

Efficiency

$$E_0 = \frac{V_0}{L} = \frac{\int_0^L (\frac{\partial E_z}{\partial r} e^{ikz}) dz}{kL}$$

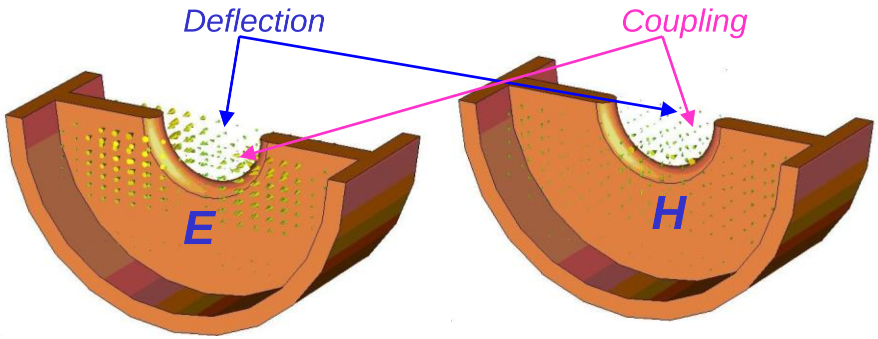
$$R_{sh} = \frac{V_0^2}{P_s} = \frac{[\frac{1}{k} \int_0^L (\frac{\partial E_z}{\partial r} e^{ikz}) dz]^2}{P_s}$$

Stability

$$E = E_n + \sum_{\nu \neq \pi} \sqrt{2} E_\nu a_\nu \frac{\delta f_j}{f_j} cos(j\pi) cos(j\nu)$$

$$a_\nu = \frac{f_\nu^2}{f_\pi^2 - f_\nu^2} \approx \frac{f_\pi}{\Delta f_\nu} \approx \frac{4N^2}{k_c \pi^2} \qquad k_c = \frac{f_\pi^2 - f_0^2}{f_\pi^2 + f_0^2}$$

DLW practically has just one degree of freedom – aperture radius R_a. Both R_{sh} and k_c are defined by R_a value, k_c increases with R_a increasing , R_{sh} decreases.

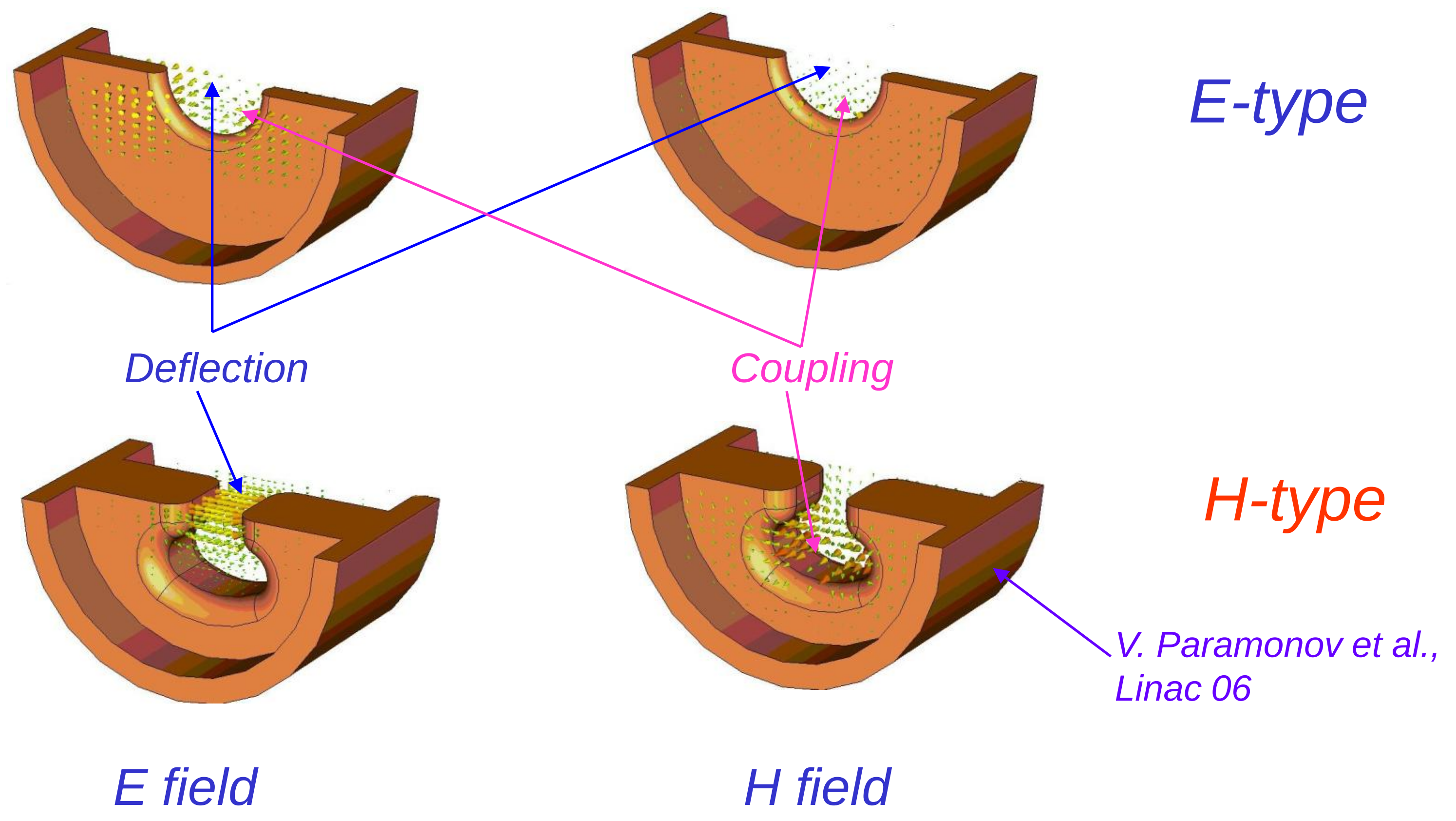


Even in S-band range only short deflecting cavities are known (N=5) [D. Alesini et al, PAC 07; P. Craievich et al., PAC 09] due to stability limitation.

S-band SW operation.

With lower frequency R_{sh} reduces, but R_a is already small ....

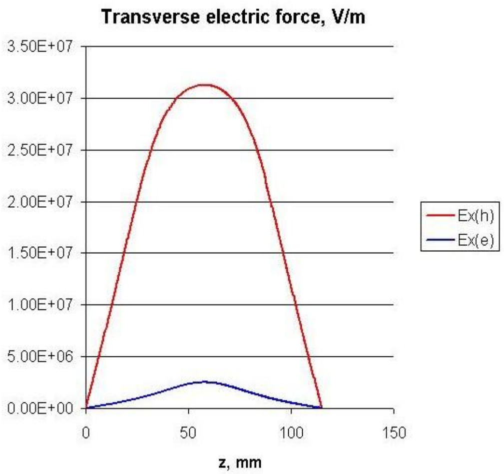
Let us decouple functions.

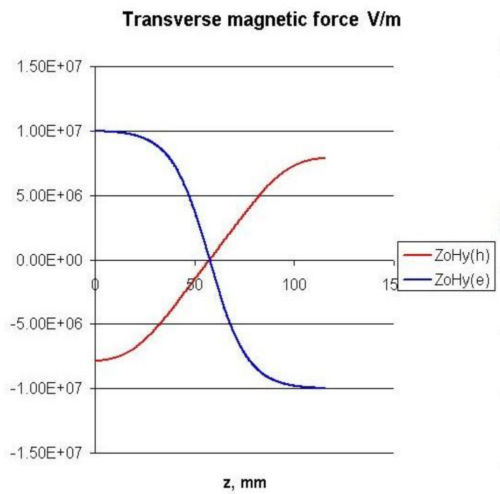


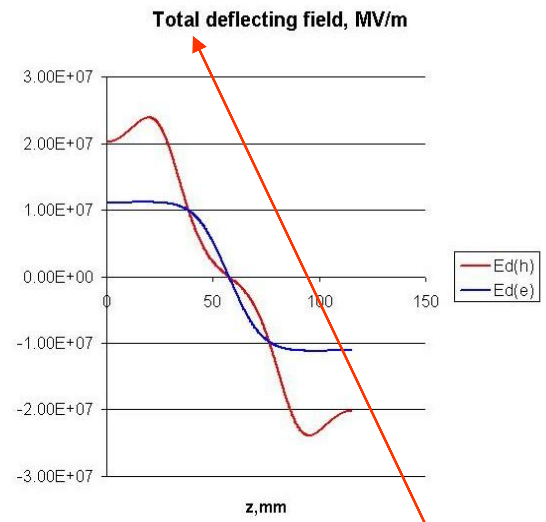
Field distributions along axis

$$\vec{F} = e(\vec{E} + [\vec{v}\vec{B}])$$

In the deflection participate transversal components both from electric and magnetic field.





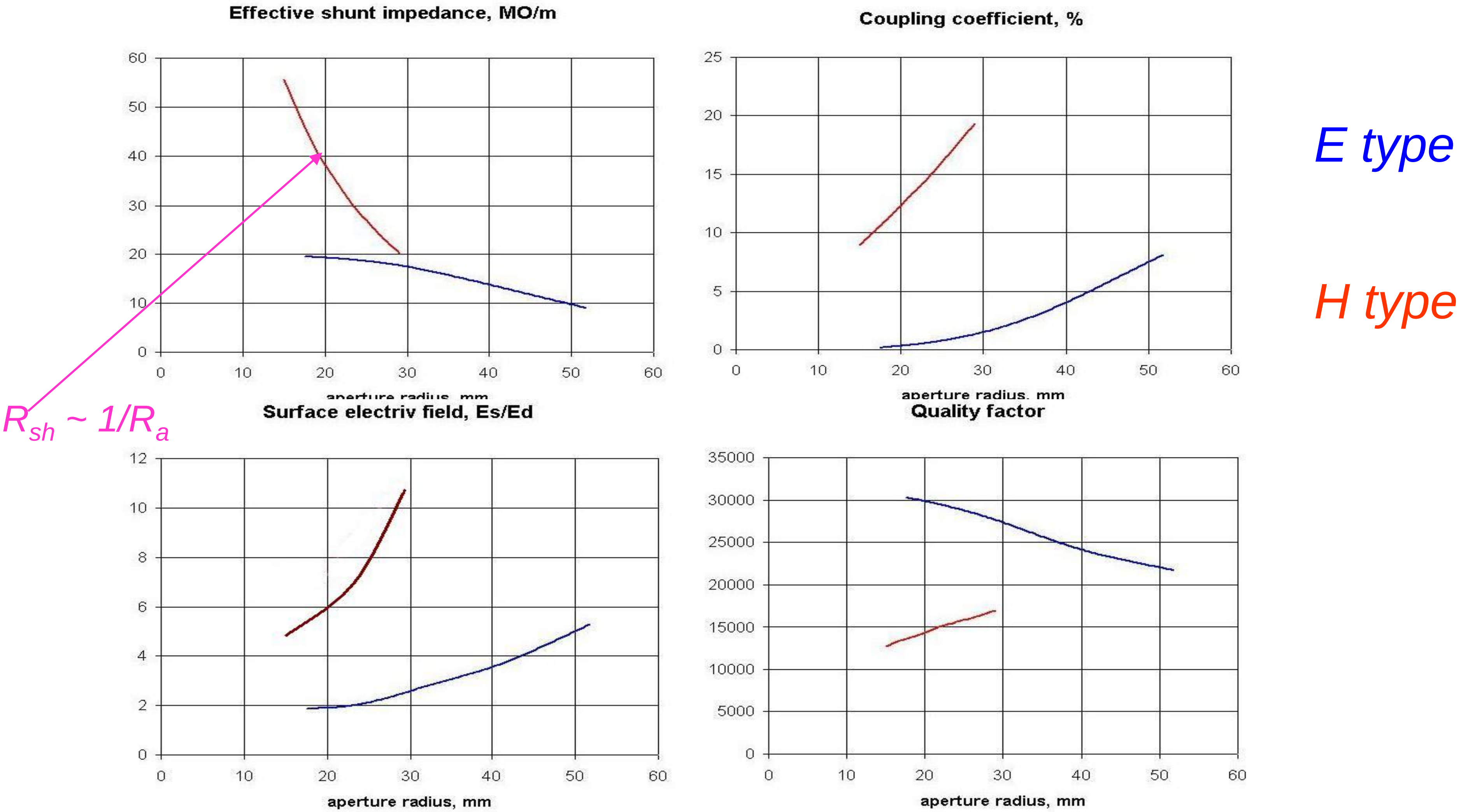


In E-type DLW transversal components work in phase,

not so in H-type …

Nevertheless…

RF parameters



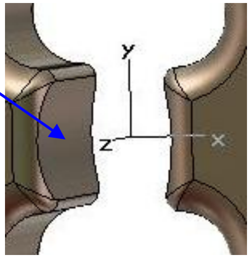
For L-band H type deflector has higher R_{sh}, higher coupling, but higher E_{smax}/E_0. In last parameter it is not optimized finally.

Aberrations

Free from aberration is just DLW (β=1) in lower HEM passband. Any deterioration of rotational symmetry automatically leads to aberrations.

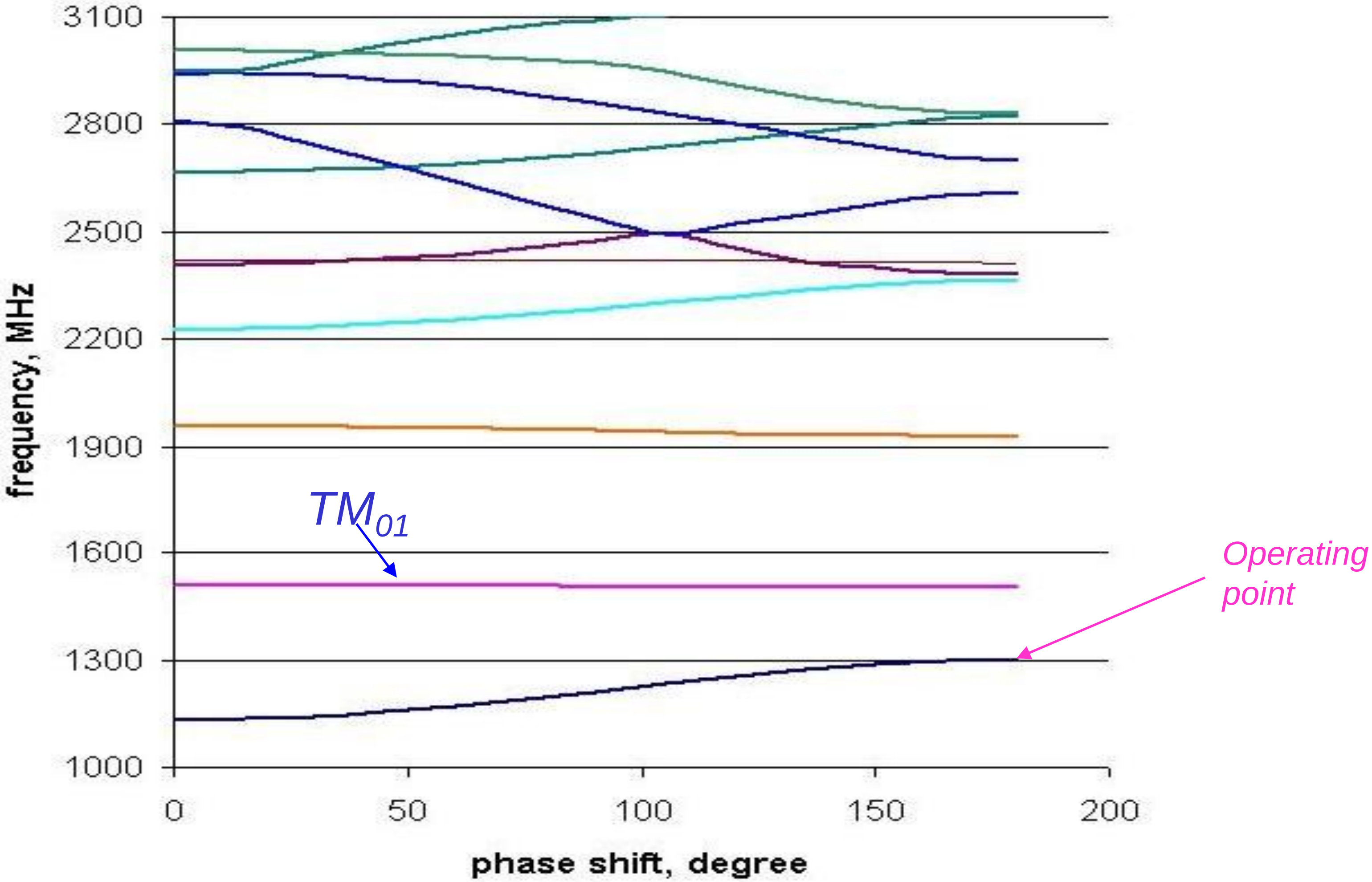
Dependence of deflection in x-direction on the y position is $\delta E_0 \sim y^2$.

Depending on R_a value, $\delta E_0/E_0 < 1\%$ for $y/R_a < 0.4$ is achievable by nose shape optimization.

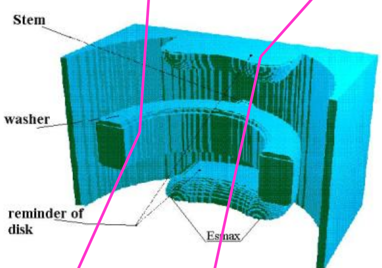


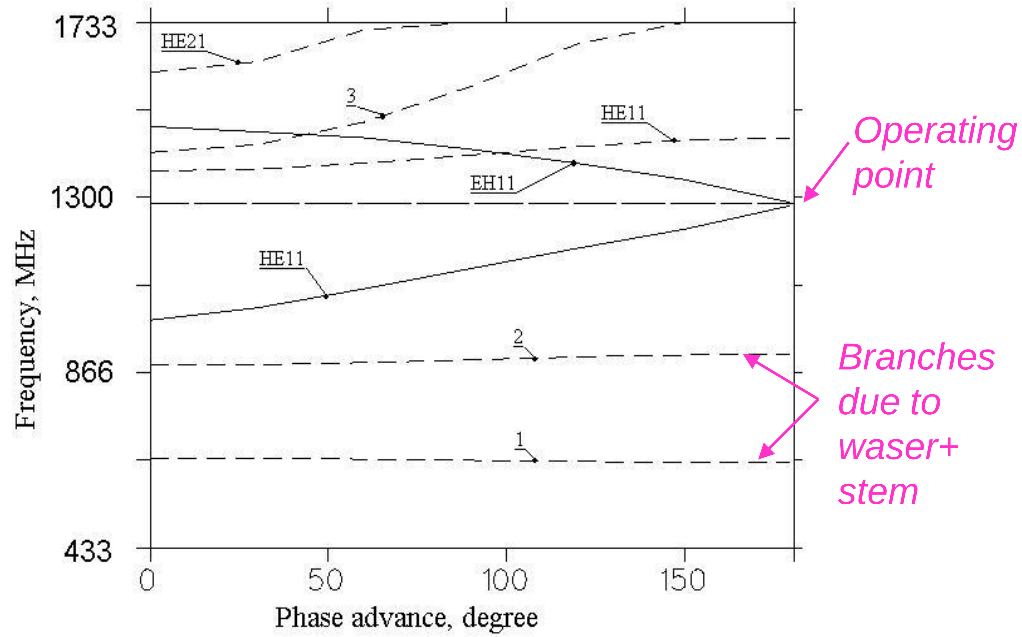
Dispersion properties

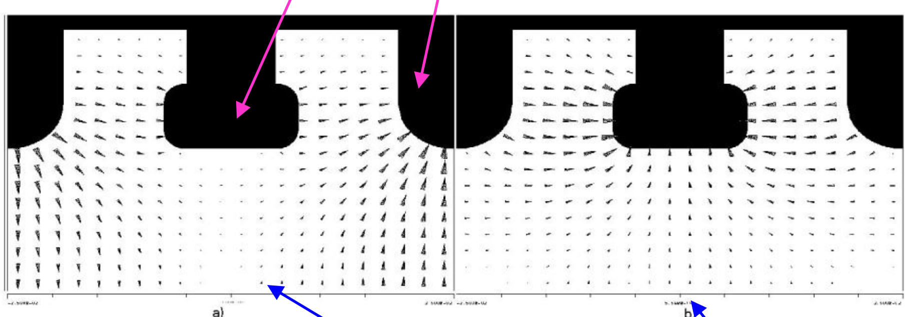
Due to small transverse dimensions, Rc ~ 0.3 l, there is no HOM problem.



Compensated RF structure (*V. Paramonov,L.Krabchuk, Linac 2000*)



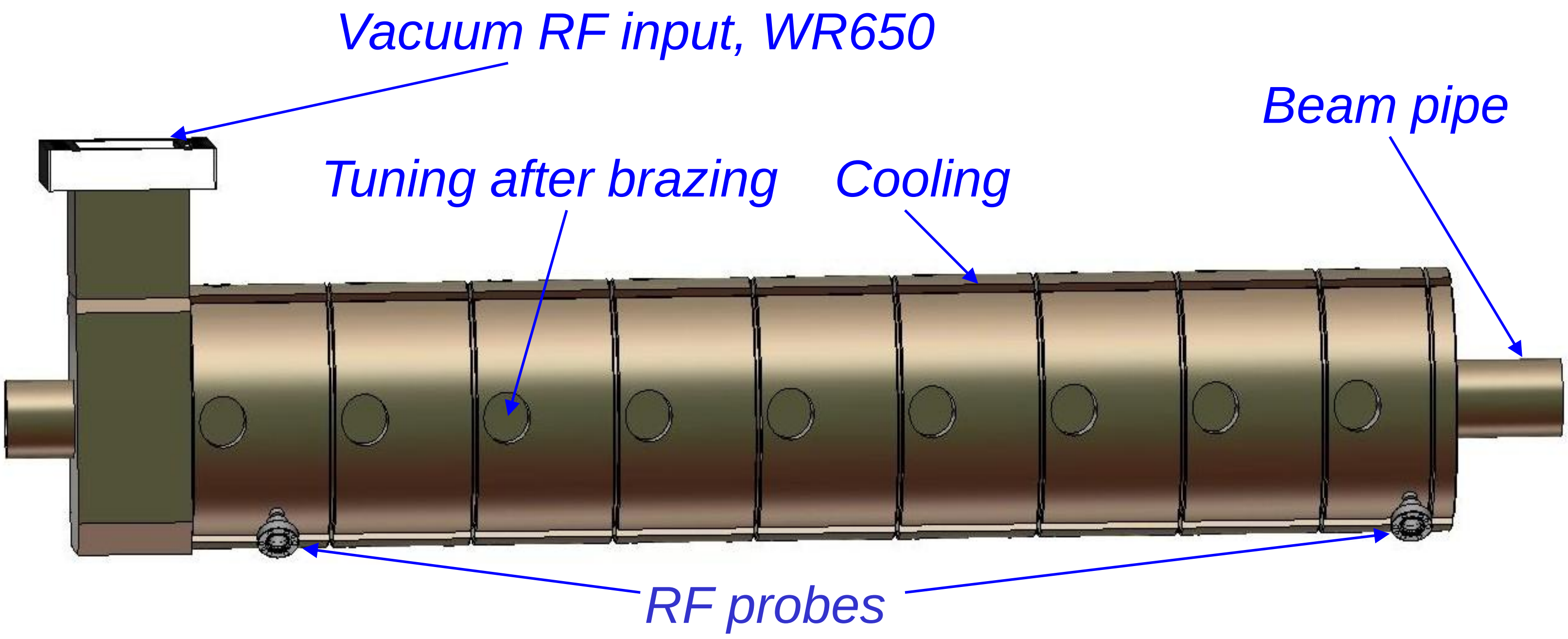




Field distribution for deflecting and coupling modes.

Has no stability problem (compensated, β_g=0.32, β=1). Efficiency ~ 0.9 from previous case. More complicated in design and dispersion properties.

Possible design



Possible parameters – R_a ~ 19 mm, R_{sh} ~ 38 MOhm/m, Q_l ~ 7000, τ_t ~ 3 ms, L~ 1 m, P~30 kW, V~ 1 MV

Summary

1. *For application in L-band frequency range normal conducting standing wave deflectors are more effective.*

2. *As compared to Disk Loaded Waveguide structure, H-type structure has higher RF efficiency, essentially higher coupling and smaller transverse dimensions.*

3. *For H-type structure tolerable values both for aberrations and maximal surface fields can be obtained by appropriate shape optimization.*

4. *The high coupling value allows longer cavities without limitations for RF coupler position.*