Effective RF Deflecting Structures for Bunch Rotation and Deflection

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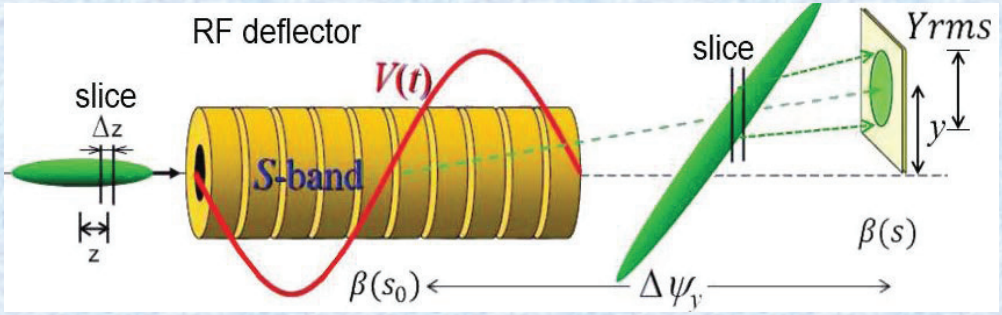
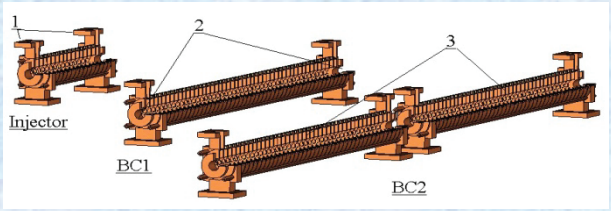
1. Deflecting Structures (DS) were introduced for bunch deflection.

2. At present time DS are mainly used for bunch rotation (bunch longitudinal diagnostic, emittance exchange, luminosity increasing).





TDS in European XFEL

3. A new applications provide new specific requirements.
4. Bunch rotation is a Particles Distribution Transformation (PDT) in 6-dimentional phase space.
5. The tool for PDT should provide a minimal, completely predictable own distortion in the original distribution, 2012

The source of distortions – non linearity in the deflecting field E_d distribution.

Field distributions analysis, basis of hybrid waves HEn, HMn.

Origination of non linear additions:

$$\vec{E} = A\vec{E}_{HE} + B\vec{E}_{HM}, \quad \vec{H} = A\vec{H}_{HE} + B\vec{H}_{HM},$$

a) not relativistic case, β <1, not evitable;

b) higher azimuthal additions – dump in design;

c) higher spatial dipole harmonics – control in design.

Original field components can not be without higher harmonics.

But Ed is composed field – there is no this prohibition!

$$E_j(r,z) = \widehat{E_j(r,z)}e^{i\psi_j(z)} = \sum_{n\to-\infty}^{n\to+\infty} a_{jn}(r)e^{\frac{-i(\Theta_0+2n\pi)z}{d}},$$

$$\vec{F}^L = e(\vec{E} + [\vec{v},\vec{B}]), F_x = eE_d = e(E_x - \beta Z_0 H_y),$$

Conclusions from field analysis

a) an opposite HE_1 and HM_1 phasing, $a_0 b_0 < 0$,
b) equalizing of amplitudes, A~-B,
c) the physical sense – keep the particle near axis and dump simultaneously higher harmonics with non linear additions in the field,
additions dumping 'in average', $a_0 \sim -b_0$, and 'ín total' $a_0 = -b_0$;
c) criterion for selection – phase deviation from the synchronous harmonic.

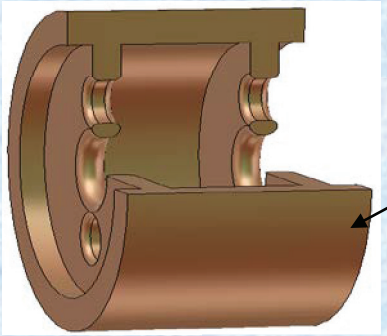
$$\delta\psi_j(z) = \psi_j(z) + \frac{\Theta_0 z}{d}, \quad \Psi_j = max(|\delta\psi_j(z)|), \quad 0 \le z \le d, r = 0.$$

$$E_{dr}(z) = \frac{e_{r0} - Z_0 h_{\partial 0}}{2} \cdot cos(\phi) + \\ + \frac{cos\phi}{2} \cdot \sum_{p=1} (e_{rp-1} + Z_0 h_{\partial p-1} + e_{rp} - Z_0 h_{\partial p}) cos(\frac{2p\pi z}{d}) - \\ - \frac{sin\phi}{2} \cdot \sum_{p=1} (e_{rp-1} + Z_0 h_{\partial p-1} - e_{rp} + Z_0 h_{\partial p}) sin(\frac{2p\pi z}{d})).$$

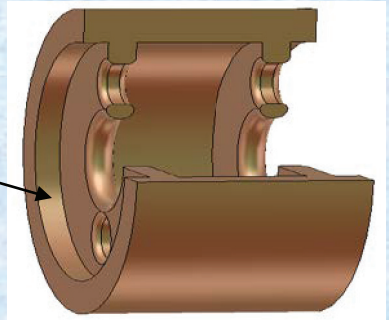
For the known structures it is an additional limitation. When you apply an additional limitations, you lose something in already achieved parameters …

How it works …

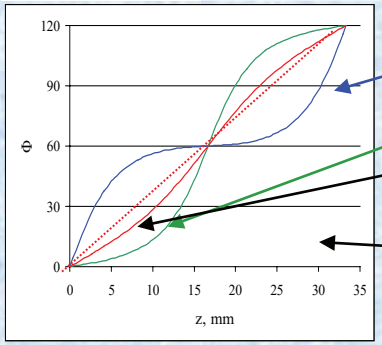
Classical structure – Disk Loaded Waveguide. A minor difference in dimensions …



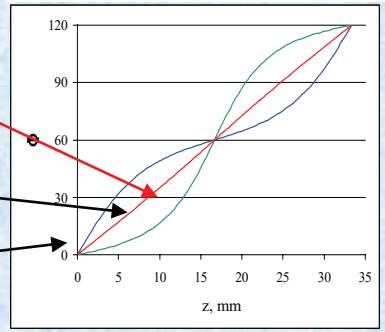
Ze =21 MOm/m, Ze=16 MOm/m



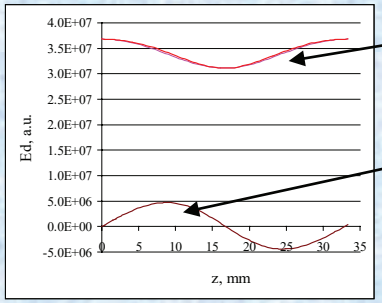
Phase Ex, Hy, Ed



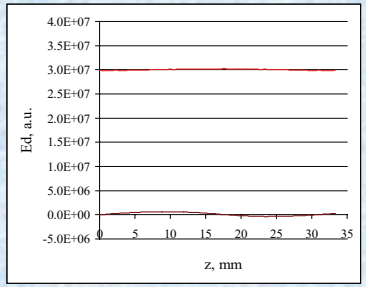
Ψ=10°, Ψ=1.20°



Deflection rotation



$$cos(d\psi_d(z)) \approx 1 - \frac{(d\psi_d(z))^2}{2}, \quad sin(d\psi_d(z)) \approx d\psi_d(z).$$



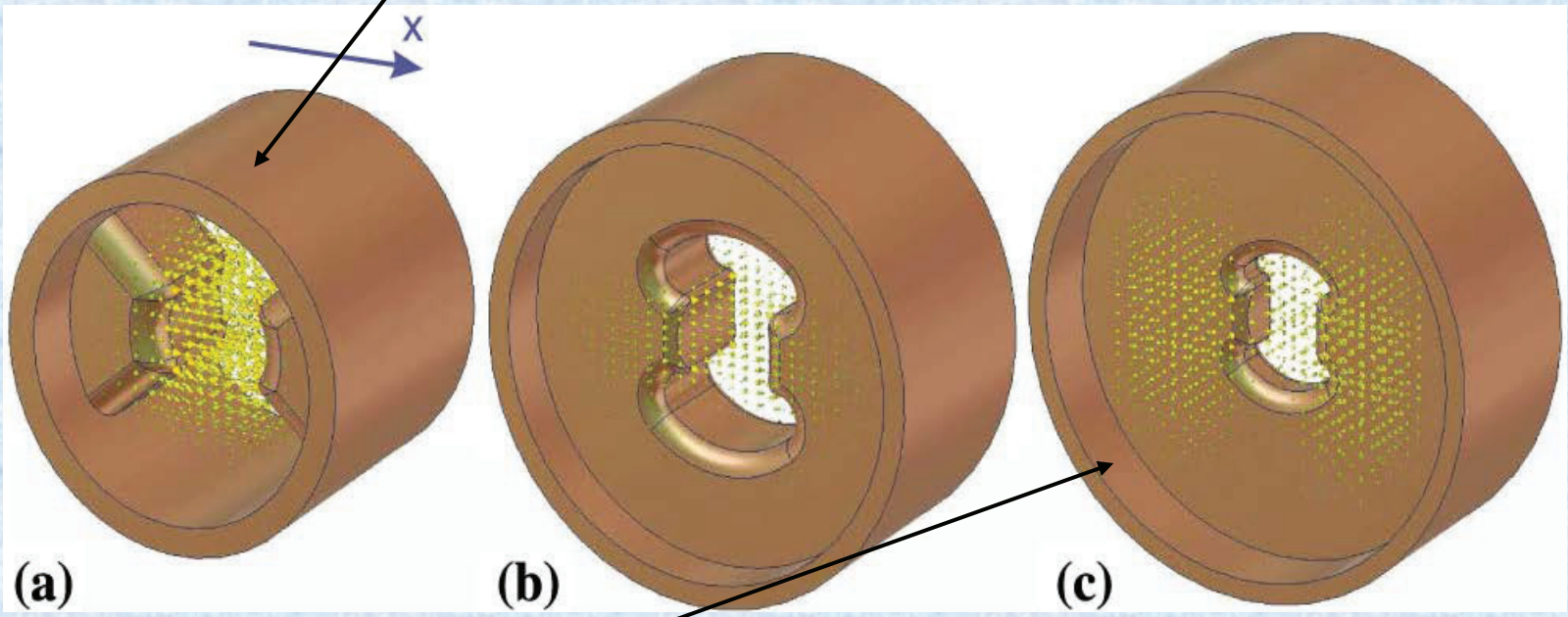
ε_t > $10^2\ \varepsilon_t$,

Two orders difference in the emittance growth.

Price - we lose RF efficiency

Our way

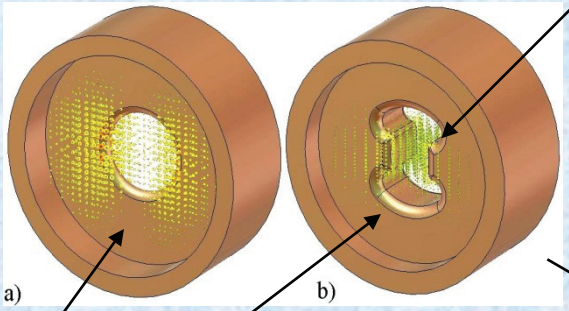
– from previous developments – convert very high RF efficiency&bad field quality into

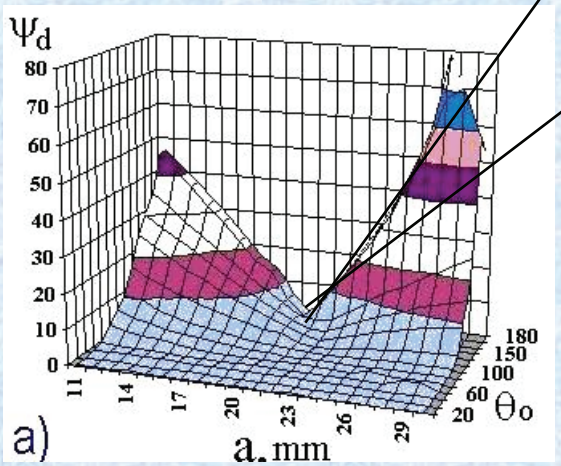


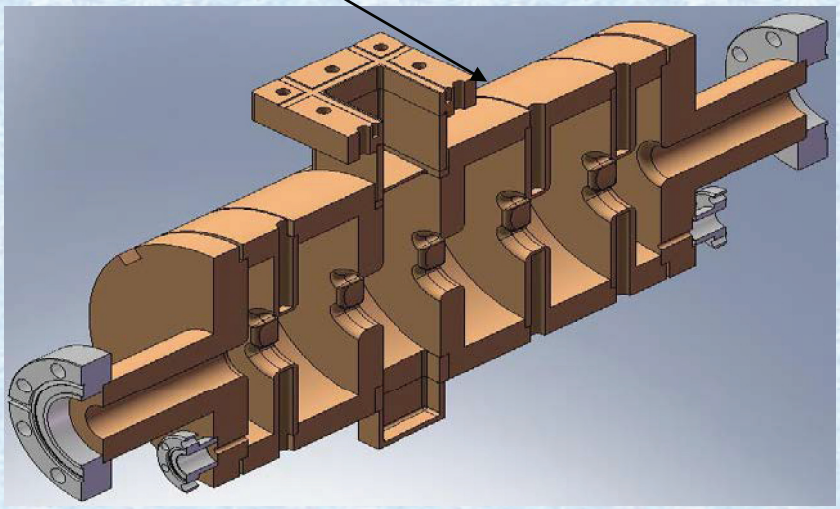
good field quality&tolerable RF efficiency, 2012

Intermediate finish, 2012

Proposal was developed, Ze=36 MOm/m

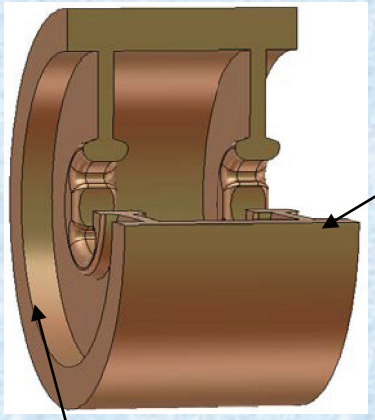




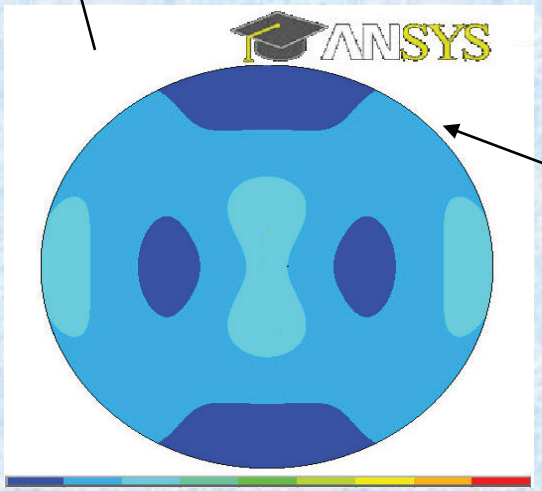


It was the first step. After that – hesitations – is this result overpaid at the expense of RF efficiency?

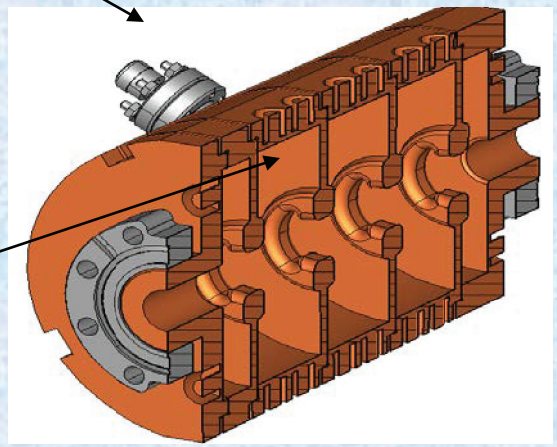
New family, origination



It appears, we really overpay …
Ze=43 MOm/m,
compensation 'in average', a_0=-1.27 b_0,
now under construction at DESY
for short bunches.



H field distribution in the middle of the gap.

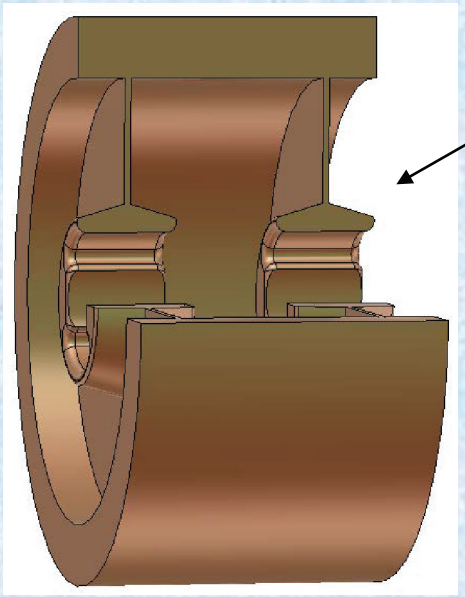


Courtesy A.Simonyan, K. Floettmann, DESY

Vanya - boy

Next family members

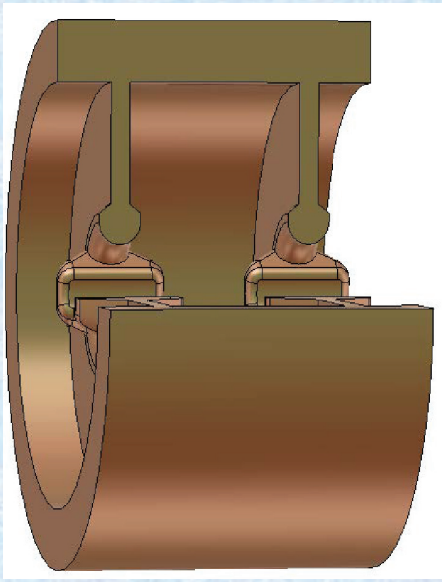
ИI



Perfect field balance,
a_0=1.007b_0, Ψ=1.05°,
second order effects,
Z_e=53 MOm/m.

If we can roll back in field quality, we get a lot in RF efficiency.
Ψ=15° -1.5°,
Ze = 93 -74 MOm/m

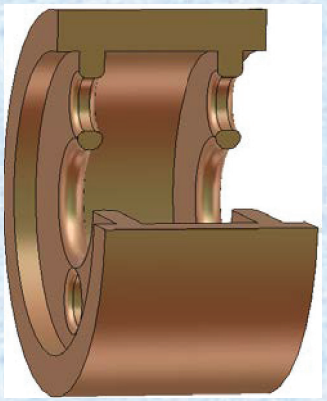
ИII



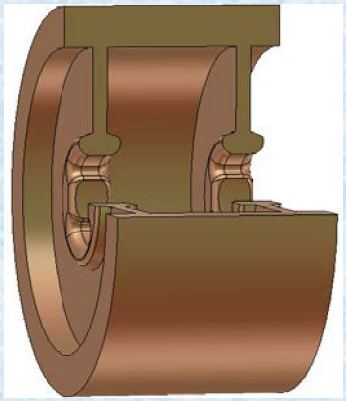
General disadvantage for SW mode

*The opposite HE_1 and HM_1 phasing, $a_0 b_0 < 0$ results in the negative dispersion (backward waves) and, especially for a0~-b0, defines **narrow band width**.*

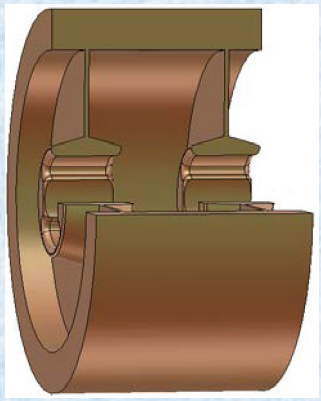
It limits the length of the cavity for SW mode and achievable V_d



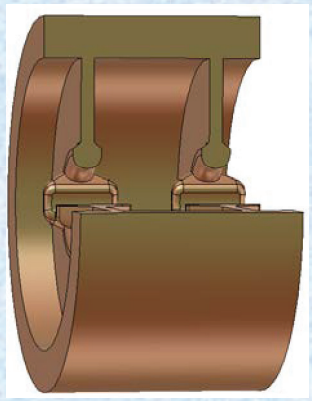
DLW



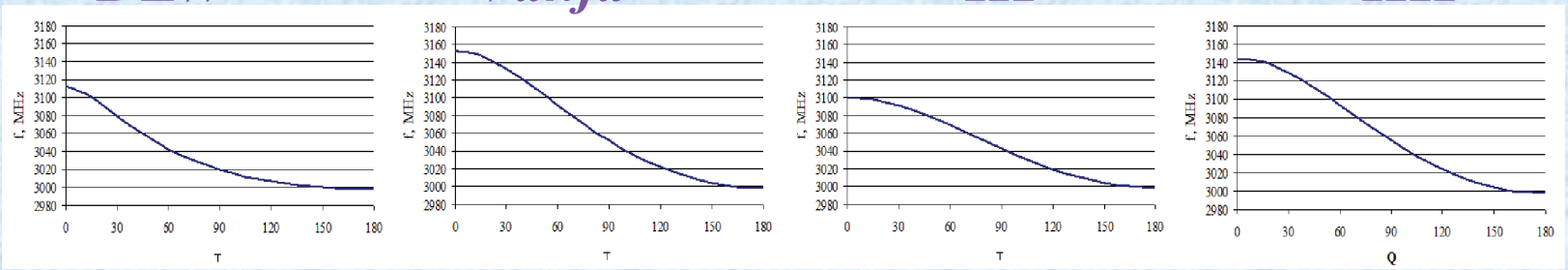
Vanja



II



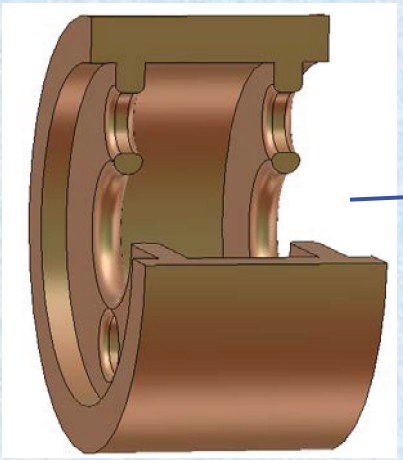
III

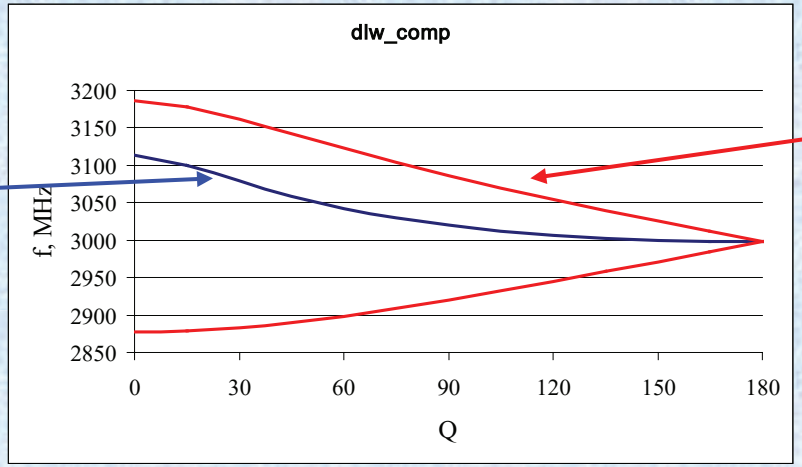


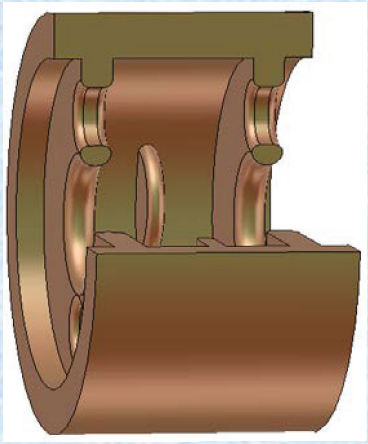
K_c 4% 5,5% 3.2% 5%

General decision – compensated options.

Compensated DLW. It is not difficult. At least six technical solutions modifications are possible …







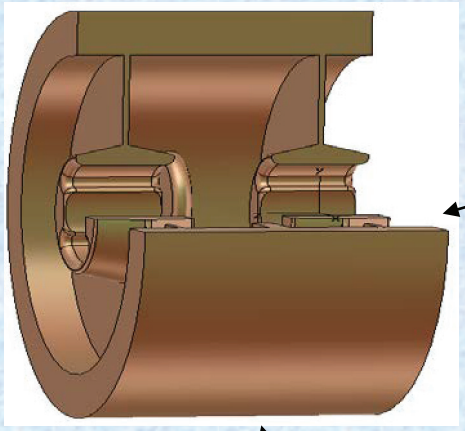
Kc=4%, *Kc=10%.*

There are no additional cell, combined field distributions.

***Not tolerable* for DLW drop in RF efficiency, Z_e=13 MOm/m. At the background of already reduced Z_e we further lose in the total set of parameters**

Compensated options for new family

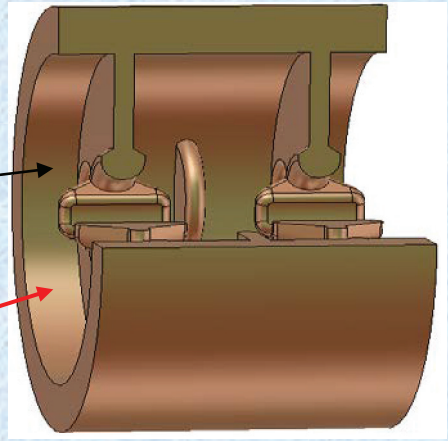
ИI-C

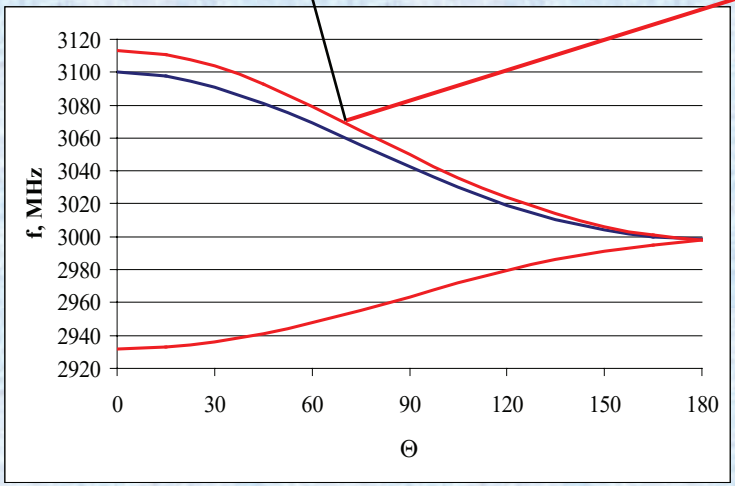


Ze~ (53 → 47)MOm/m,

Ze (93 → 86)MOm/m

ИII-C

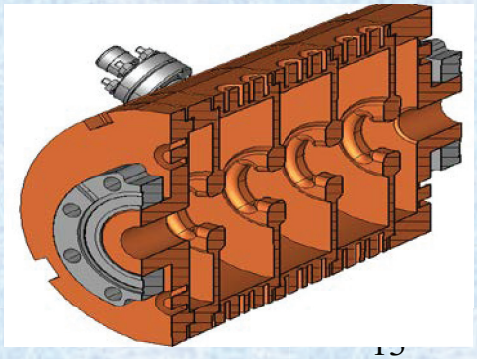




If we have much higher Ze value, reduction at 6-7 Mom/m becomes the tolerable price for qualitative higher stability of the field distribution

Summary

New family of deflecting structures is developed with the main feature of careful bunch handling during transformation of particle distributions due to minimized own DS aberrations.
Even with this new quality, developed structures have excellent RF efficiency and can be used for simple deflection.
Instead of more complicated shape and more limiting criteria, structures are developed following to the concept of separated control for each parameter.
Results of this development are requested by community and we start promotion of this structures into research facilities. The first will be soon. We expect operating results in Spring 2017.
The line for another options is in discussion.



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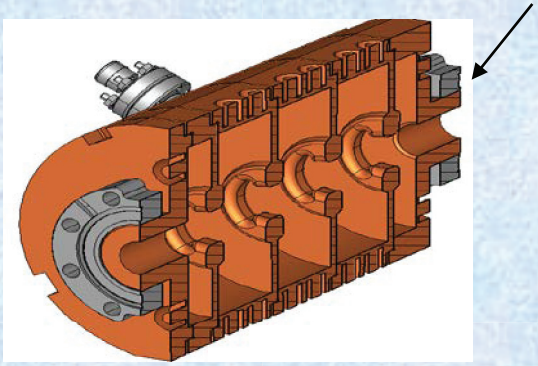
Especially warm thanks to Klaus Floetmann, DESY, for support in collaboration and beam dynamics expertise.

Thanks to CANDLE team – technical design and construction.



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