Studies on externally applied m=0 modes in the RFX-mod RFP

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Outline of the presentation

- description of the experiments
- description of the linear model
- interpretation of experimental results
- Conclusions

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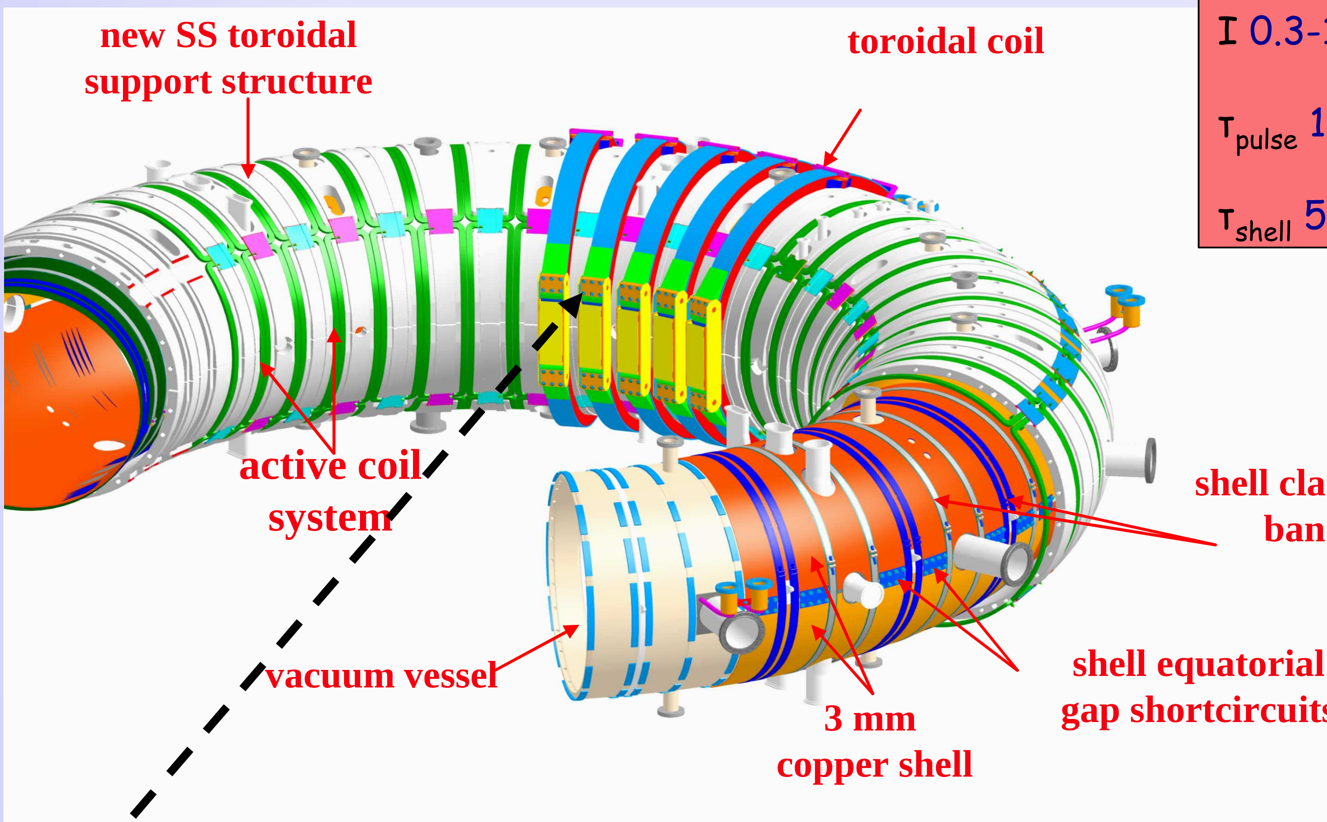
RFX-mod

48x4 active coil system 100% surface coverage



R 2 m

a 0.46 m

I 0.3-1.1 MA

τ_{pulse} 100-200 ms

τ_{shell} 50 ms

Experiments performed with the 48 toroidal field coils (4 sectors and 12 independent currents)

4X48 sensors (radial and toroidal)

The theoretical model

By using an approach similar to *Paccagnella et. al. Nucl. Fus. 42 (2002) 1102*

Fourier decomposition

$$b(r,\vartheta,\varphi,t)=\sum_{m,n} b_{m,n}(r;t)\exp[i(m\vartheta+n\varphi)]$$

Thin shell jump conditions

$$\tau_w \frac{\partial b_{m,n}^{rad}}{\partial t} = r_w \left[\frac{\partial b_{m,n}^{rad}}{\partial r} \right]_{r_w^-}^{r_w^+}$$

Coils jump conditions
In the poloidally symmetric case

$$\left[\frac{\partial b_{m,n}^{rad}}{\partial r} \right]_{r_c^-}^{r_c^+} = 0$$

final relation

for toroidal field

$$b_{0,n}^{sens} = a_{0,n} M_{0,n} b_{0,n}^{fc}$$

with

$$M_{0,n} = \frac{1}{2\tau_w\,(s+\Gamma_{0,n}^w)} \cdot \frac{1}{K_0'(|n|\varepsilon_w) I_0'(|n|\varepsilon_c)}$$

$$a_{0,n} = \frac{\mathrm{sgn}(n)}{|n|\varepsilon_w} \cdot \left[\frac{2\tau_w \Gamma_{0,n}^w}{|n|\varepsilon_w} - \frac{K_0(|n|\varepsilon_w)}{K_0'(|n|\varepsilon_w)} \right]$$

and

$$b_{0,n}^{fc} = -\frac{\mu_0}{\pi a} \cdot \left[-\pi n^2 \varepsilon_c \varepsilon_w K_0'\left(|n|\varepsilon_w\right) I_0'\left(|n|\varepsilon_w\right) \right] \cdot F_{0,n} \sum_{\nu=-\bar{n}}^{+\bar{n}} I_{0,n'}^{coils}$$

Note the summation over the sidebands generated by the finite set of coils

$$n' = n + \nu N_c$$

Nc = 12 for this study

with

$$F_{0,n} = -i\, N_c / 2\pi n$$

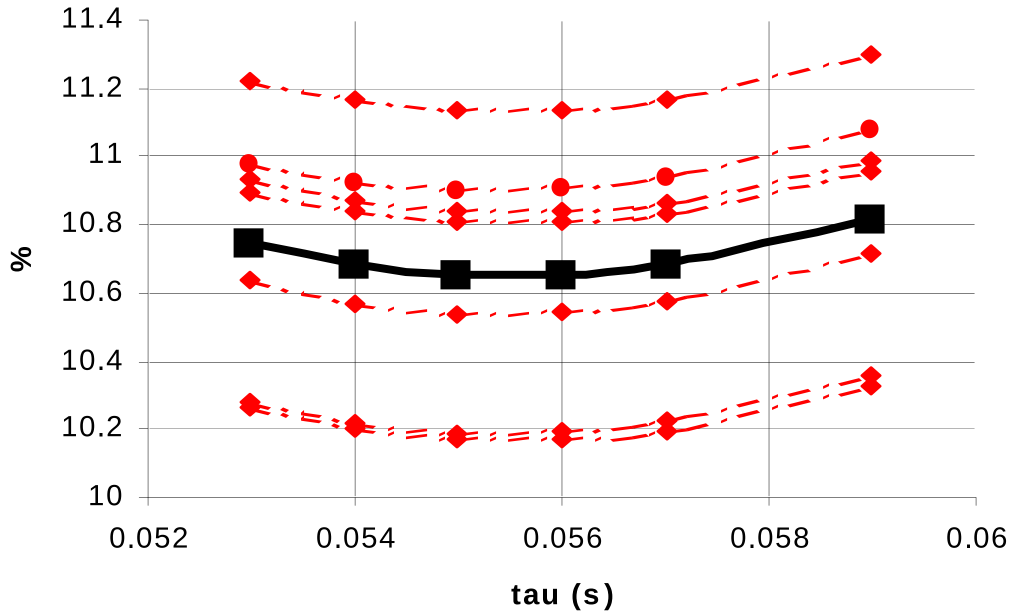
Coils form factor

Therefore finally we obtain a relation of the type:

$$b_{0,n}^{sens} = P(s) \sum_{n'} I_{0,n'}^{coils}$$

where P(s) is the transfer function between applied currents and measured fields in the Laplace transformed space

Vacuum experiments

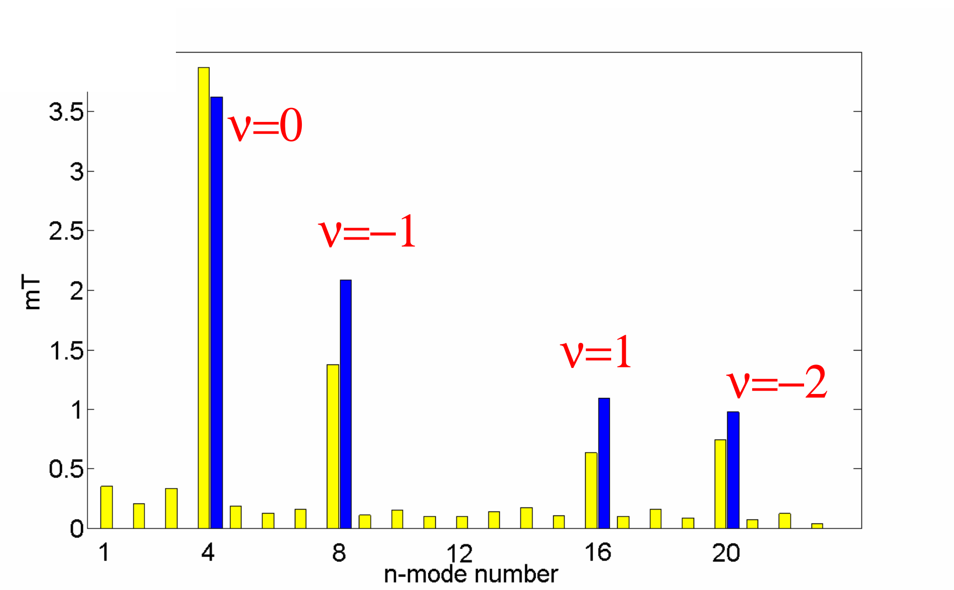


$$rms^2 = \sum_k \left(b_{meas,k} - b_{calc,k}\right)^2 / (N-1)$$

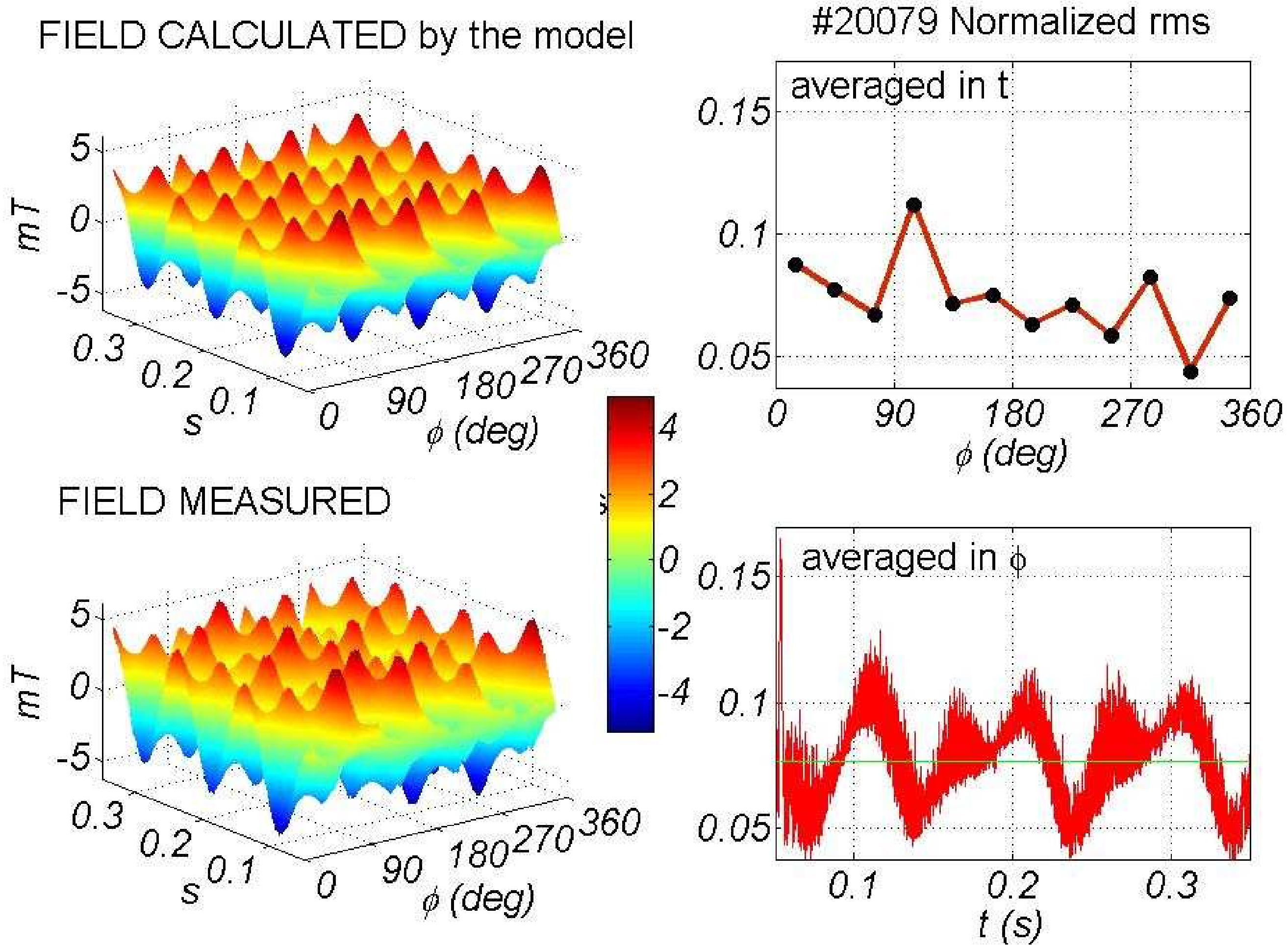
(sum over 12 positions)

Reconstruction error
vs. wall time
(for a rotating (10Hz) 0/4
perturbation)

measured (yellow) and
reconstructed (blu)
m=0 harmonics
(n=4 applied)

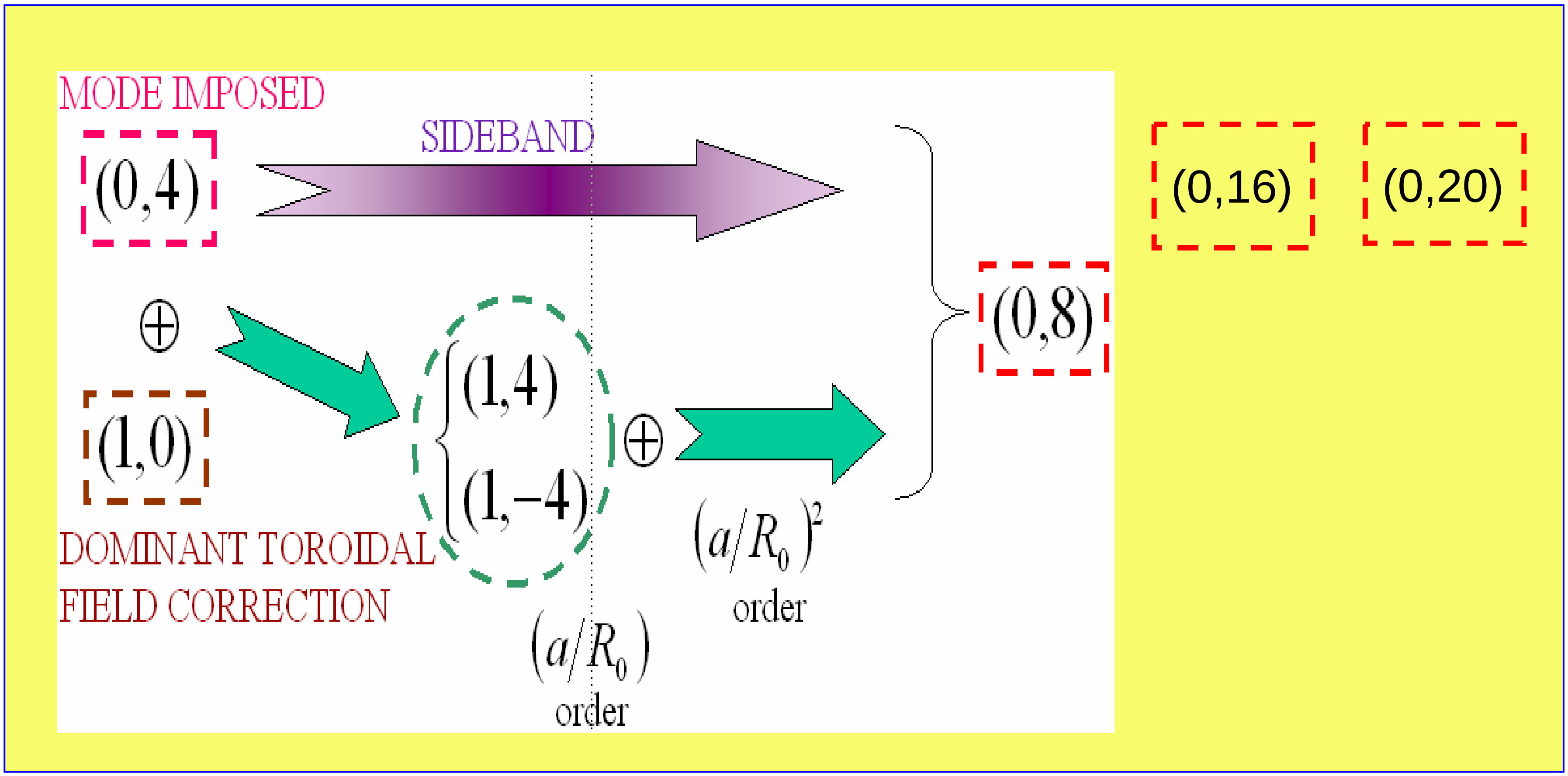


Vacuum experiments

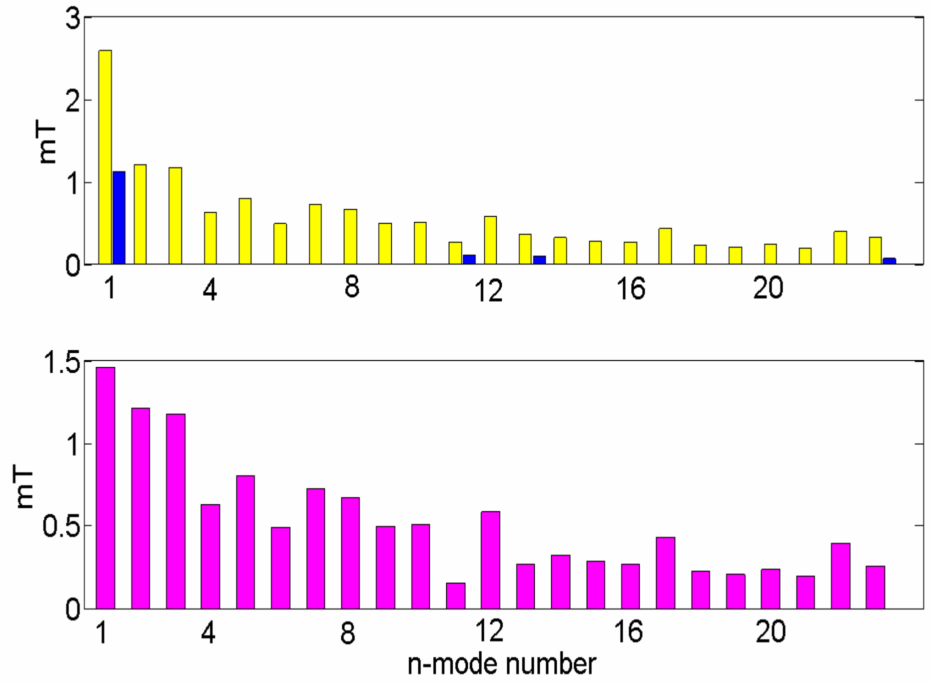


Vacuum experiments

Mode coupling scheme



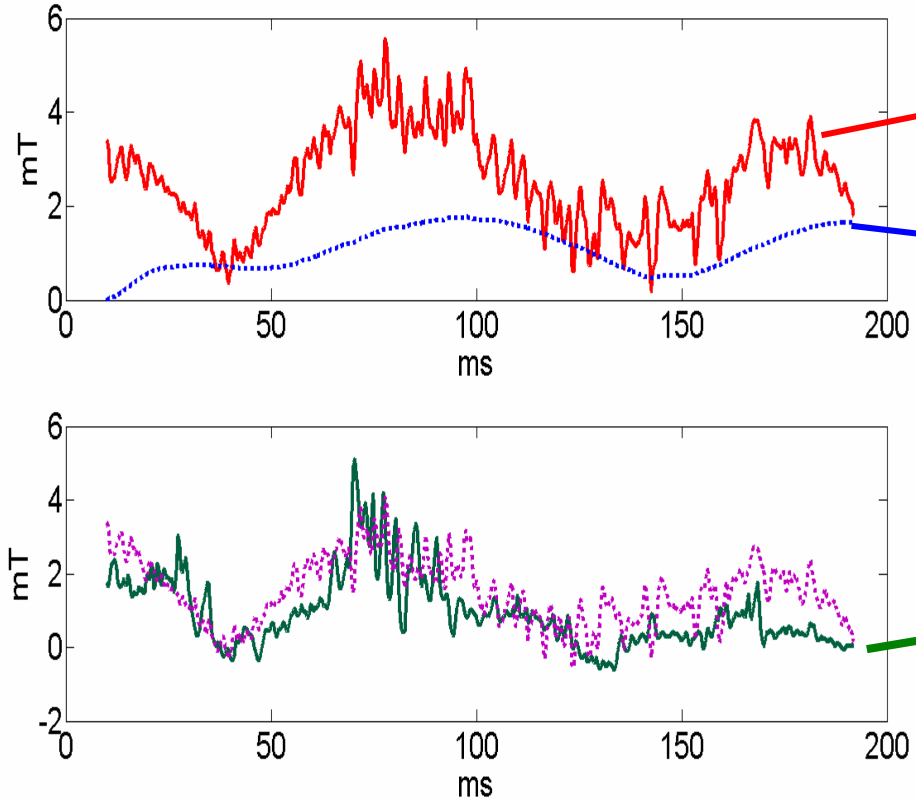
Plasma experiments



Yellow → measured
Blu → externally generated field

Plasma calculated response

Plasma experiments (0,1) applied field

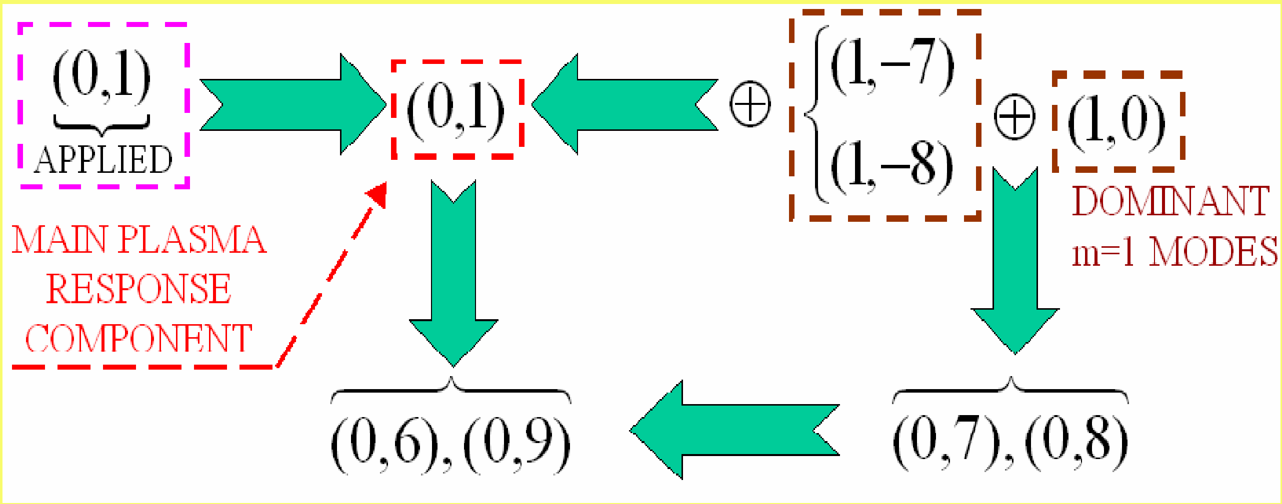


Plasma calculated response
(measured-externally applied)

Coils produced field
(calculated by the model)

(0,1) calculated from
dominant m=1 modes
(n= -7 and n= -8)

Mode coupling scheme [(0,1) applied perturbation]

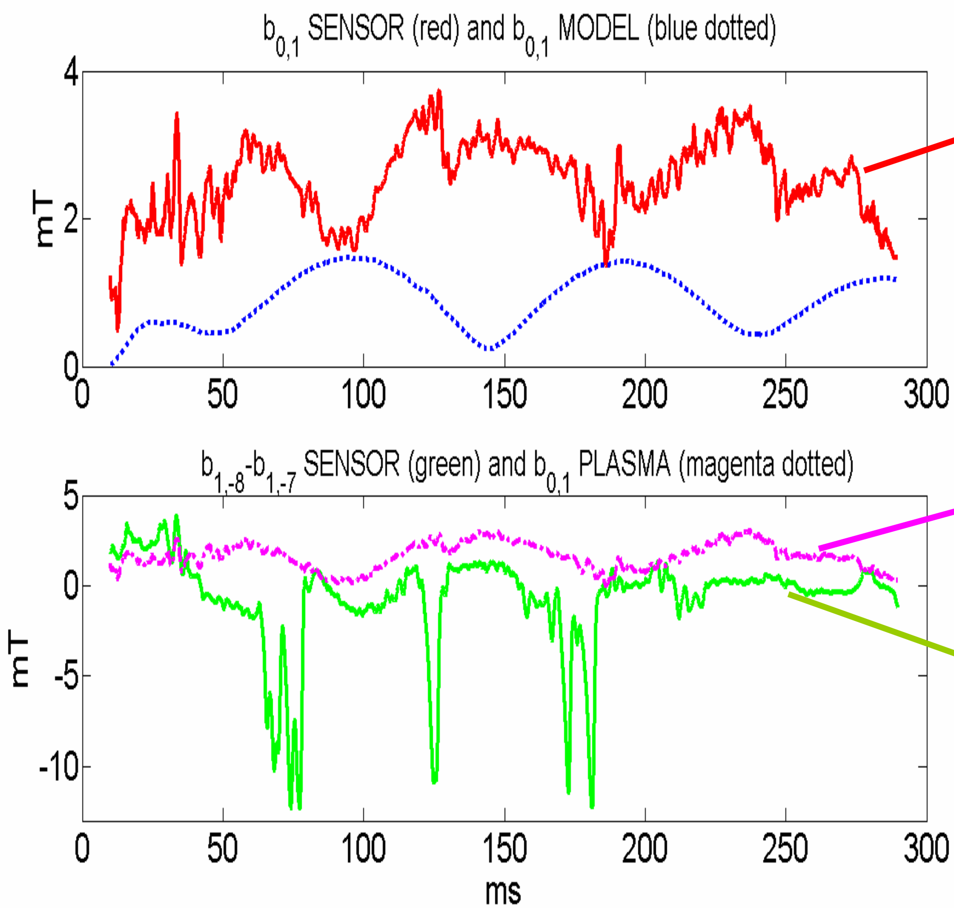


(many harmonics self-generated by the plasma not explained by this coupling scheme)

Plasma experiments

(0,1) applied field

Case with a dominant oscillating mode



measured field

Coils produced field
(calculated by the model)

Plasma calculated response
(measured-externally applied)

(0,1) calculated from
dominant m=1 modes
(n= -7 and n= -8)

Comparison less satisfactory in this case...

Conclusions

- a finite set of coils generate sidebands (!)

- in actively (externally) generated fields it is very important to have models which are able to extract the "true" plasma response

- the sidebands and toroidal effects complicate the picture of mode coupling

- It is however shown here that using a "model based data analysis" the "conventional" RFP picture of mainly nonlinearly generated m=0 modes emerges (for standard cases -> no dominant mode)

(more systematic studies are still needed..)

understanding/modelling modes coupling schemes is very important...not only for the RFPs !