Physics Aspects of the Dynamic Ergodic Divertor (DED)

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Outline

Motivation, aims

Experimental set-up

Ergodic zone

Laminar zone

Dynamic Aspect

Motivation:

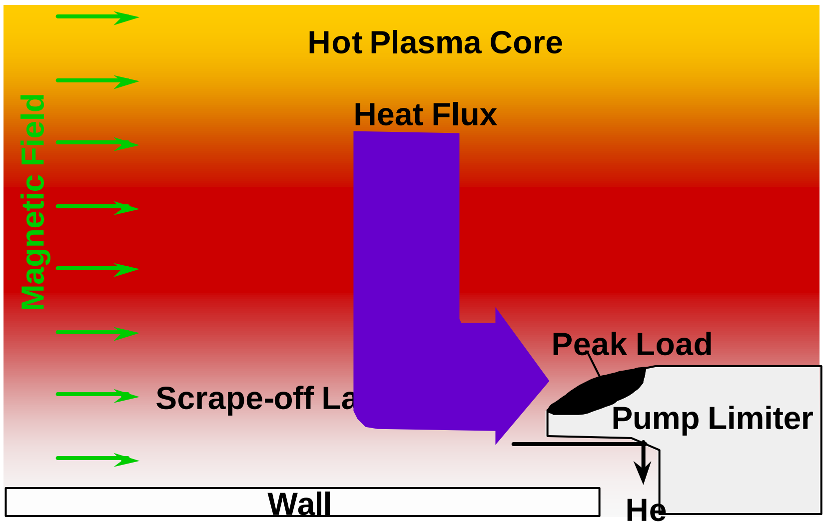
• The next fusion device (ITER) will have a fusion power of about 1.5 GW

• ===> 300 MW a-particle heating

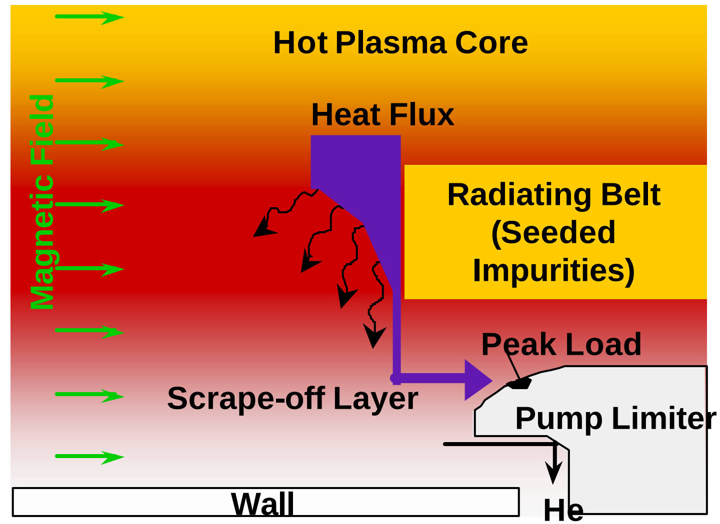
• This power goes to divertor plates, if plasma edge is not radiatively cooled

• Assuming a divertor length of 30 m and a strike point width of 2 x 4 cm ==> power density of 12.5 kW/cm^2

• For these power fluxes, no technical solutions are known



Plasma Edge Radiation: too low
Limiter Heat Load: excessive

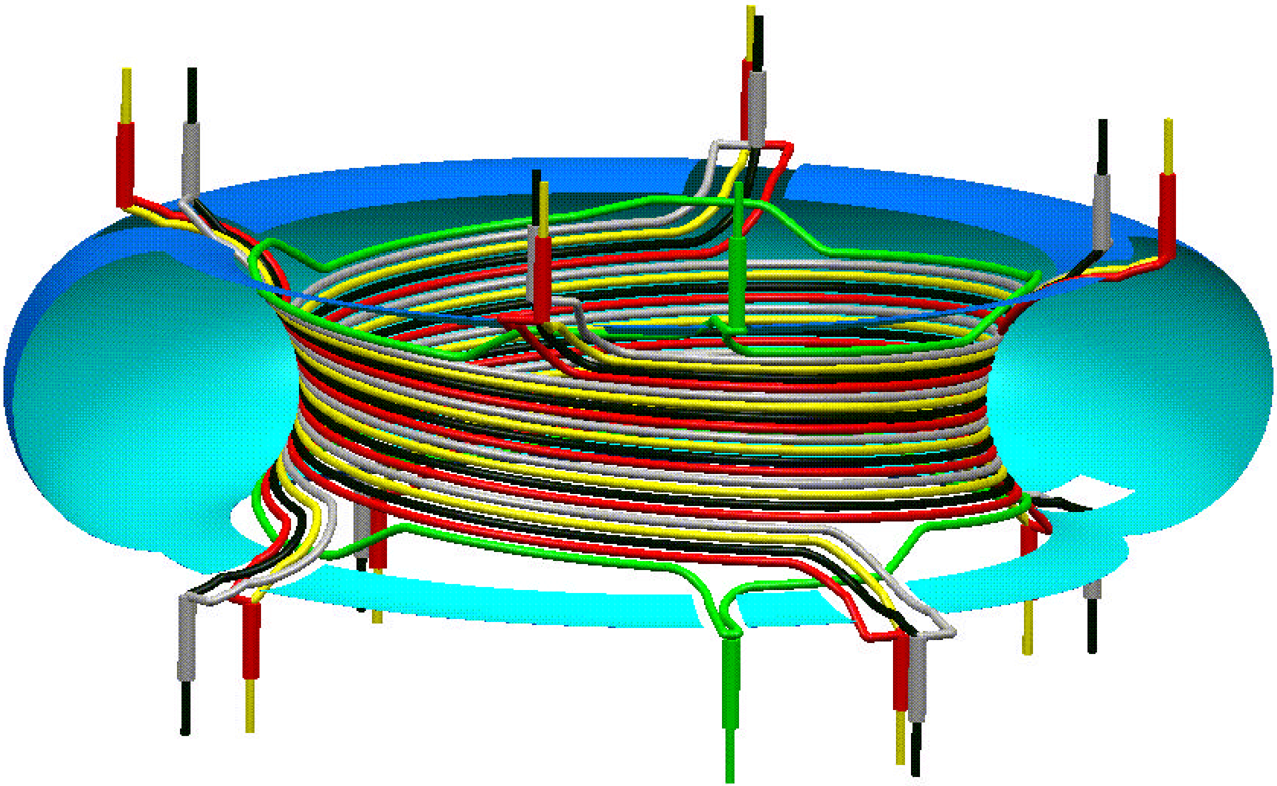


Plasma Edge
Radiation: dominating
Limiter Heat Load: tolerable

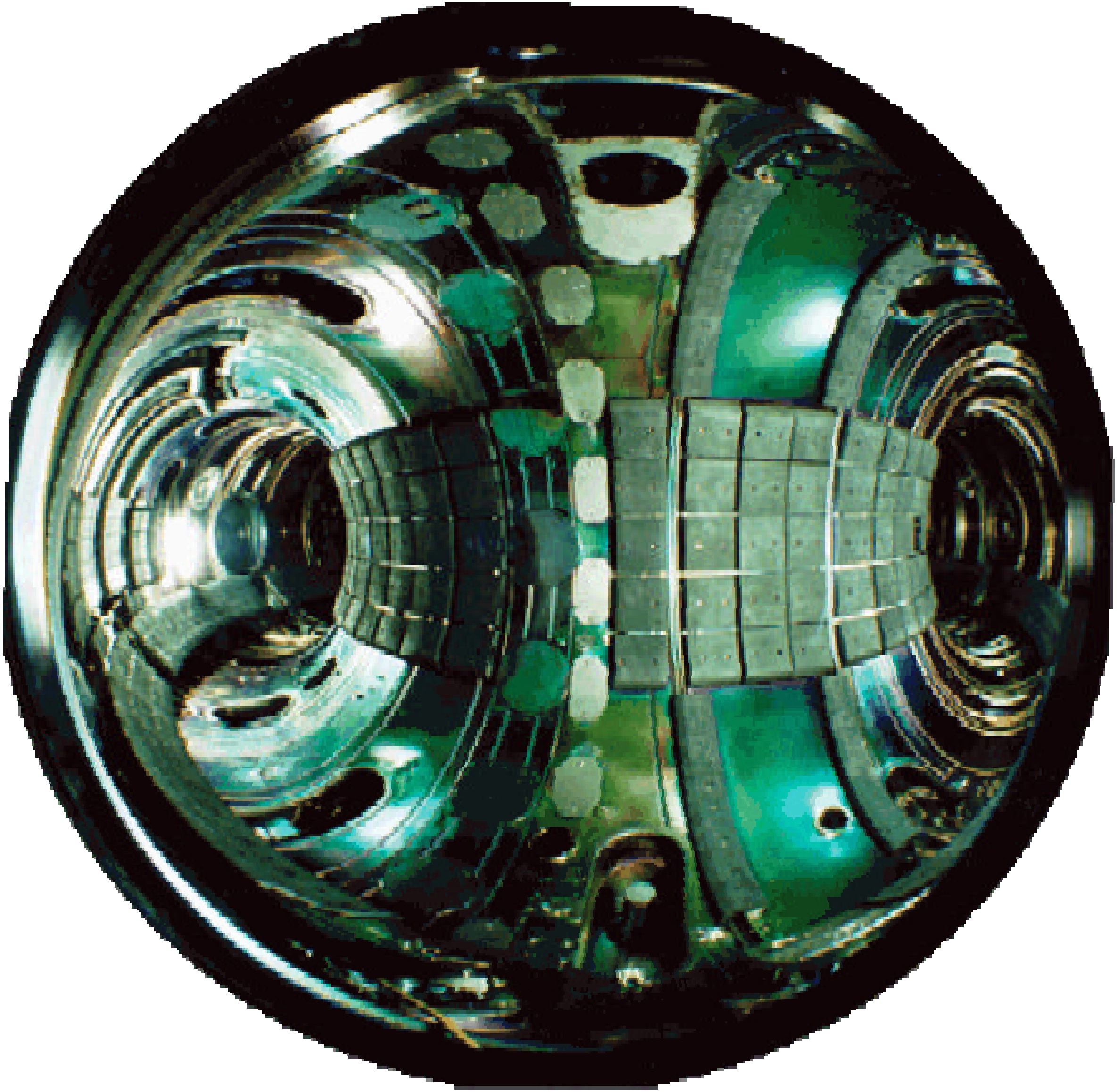
TEC

Set-up

- **4 quartets of perturbation coils plus two compensation coils**
- **4 Phases ===> Rotation of perturbation field**
- **f: DC, 50 Hz, band 1 kHz - 10 kHz**
- **Arrangement at HFS with continuous winding in vessel**
- **Maximum perturbation current: 15 kA**
- **Resonance: $q(r_{res}) = 3$; $r_{res} = 0.43 \ldots 0.46$ m (a=0.46 m)**
- **Base modes: m/n = 12/4; 6/2; 3/1 and mixture of 12/4 + 6/2**

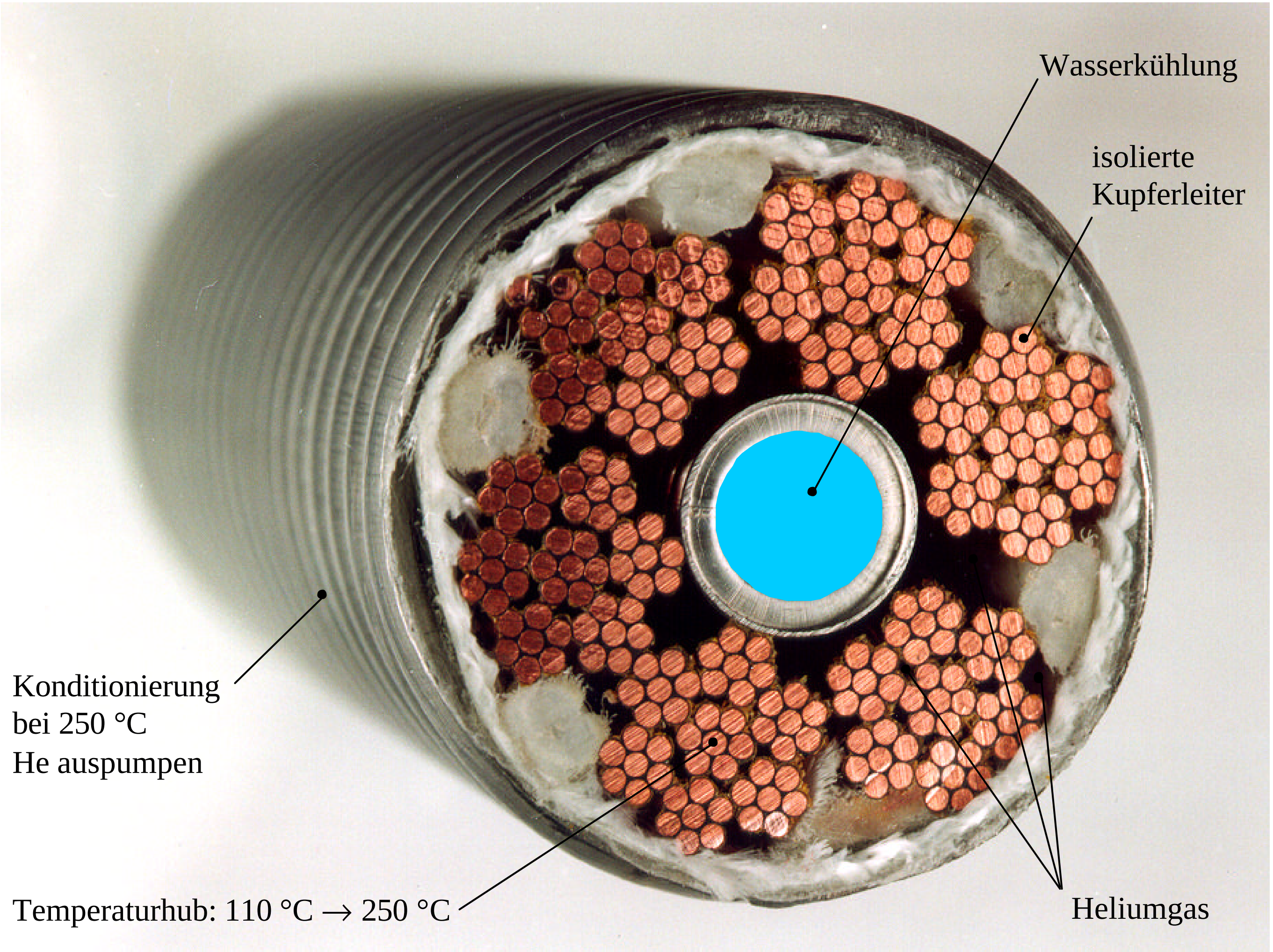


Final coil design



Wide angle view in TEXTOR

DED - Spulenkühlung



Scientific aims for DED program

DC-operation

- **Comparison to other ergodization experiments**
- **Optimisation of the radiation belt**
- **Optimisation of particle exhaust**
- **Investigation of a helical divertor**

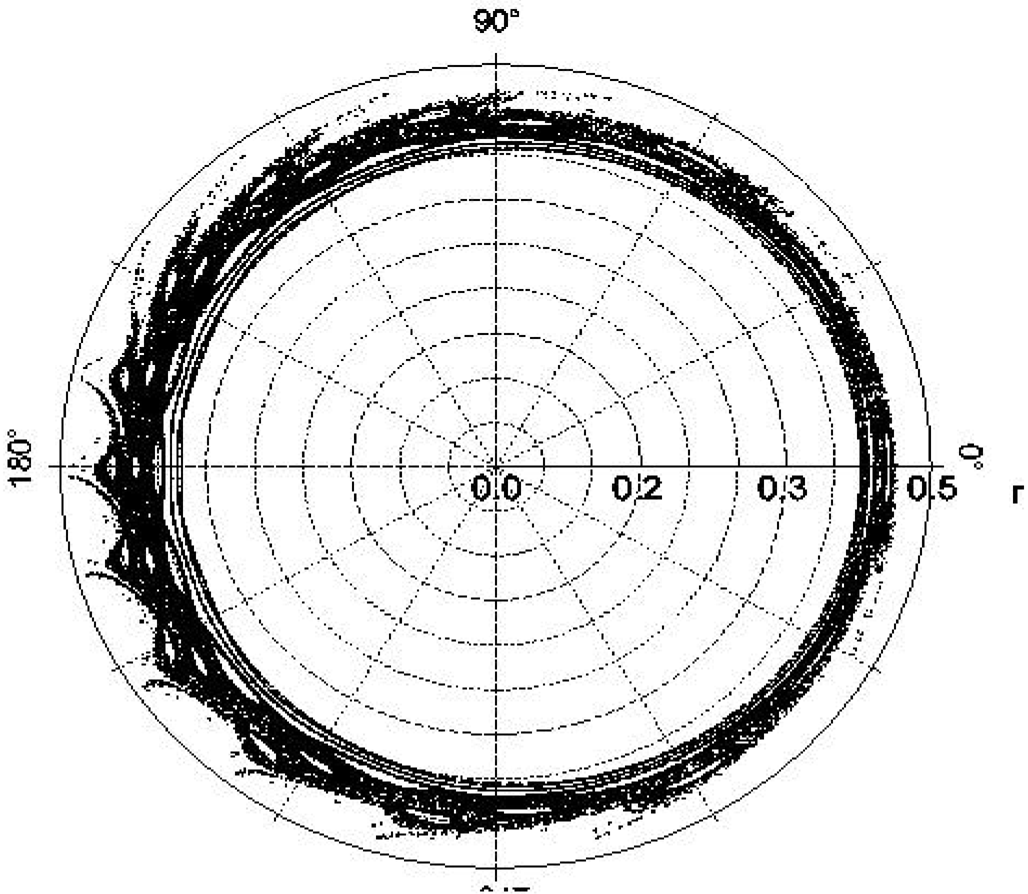
Low frequency operation:

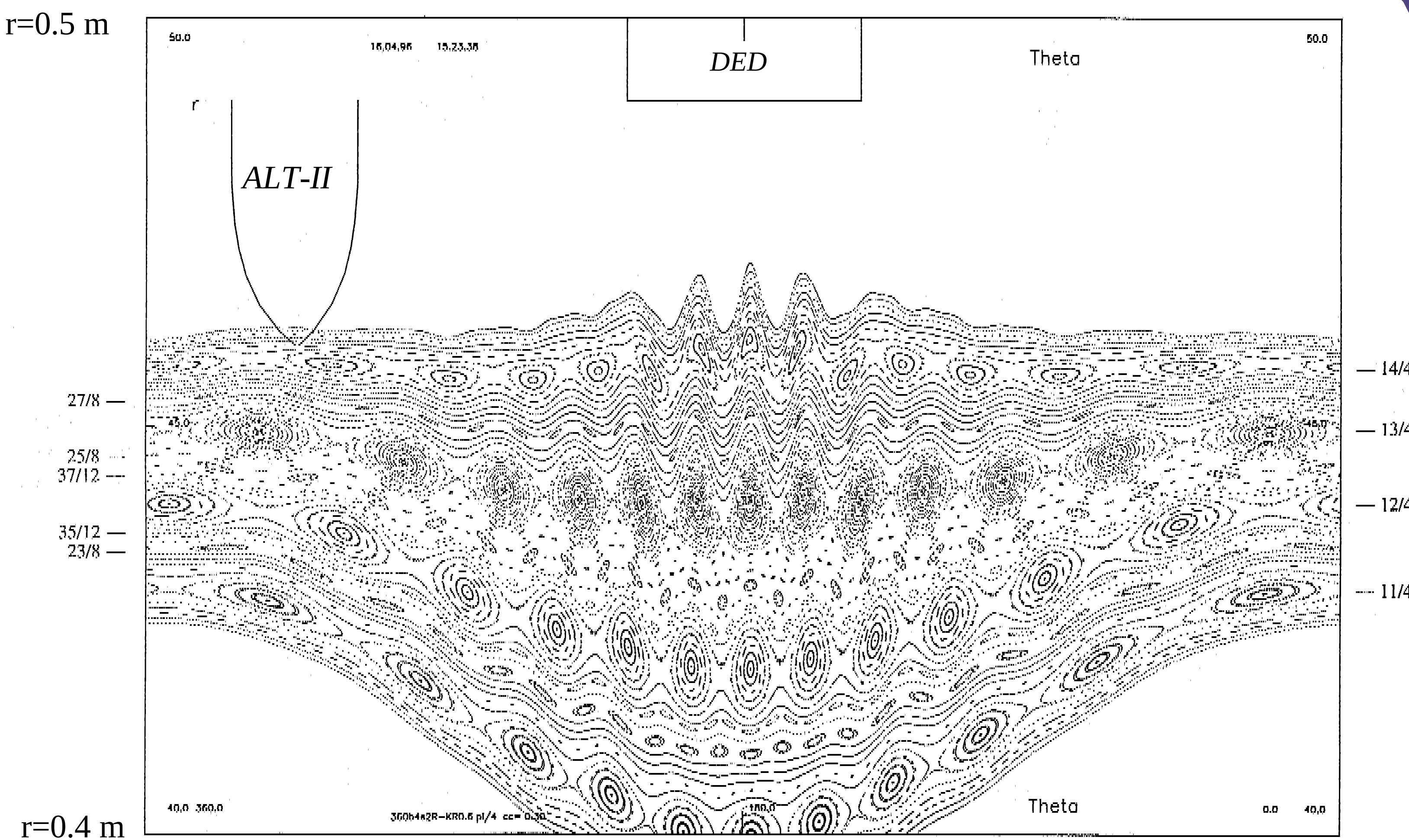
- **Smearing out of local peaks of heat flux**

1 kHz - 10 kHz operation

- Smearing out of local heat fluxes
- Generation of temporal ergodization
- Generation of a differential plasma rotation
- Improvement of plasma confinement
- Delay of disruption limit
- Plasma compression in front of pump limiter

I_{pol} = 480 kA , r_{res} = 44.26 cm



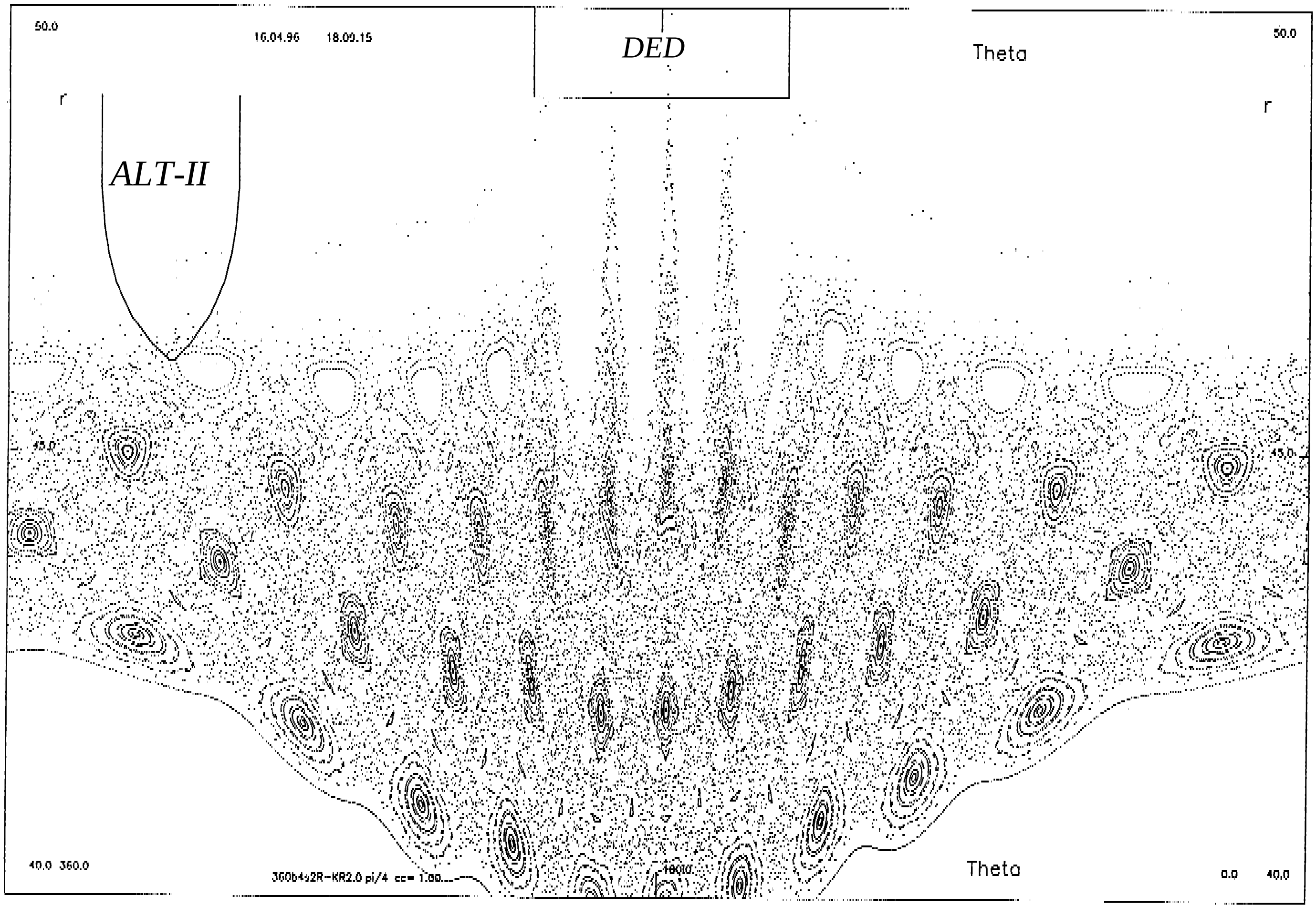


Θ = 360°

30 % perturbation current

Θ = 0°

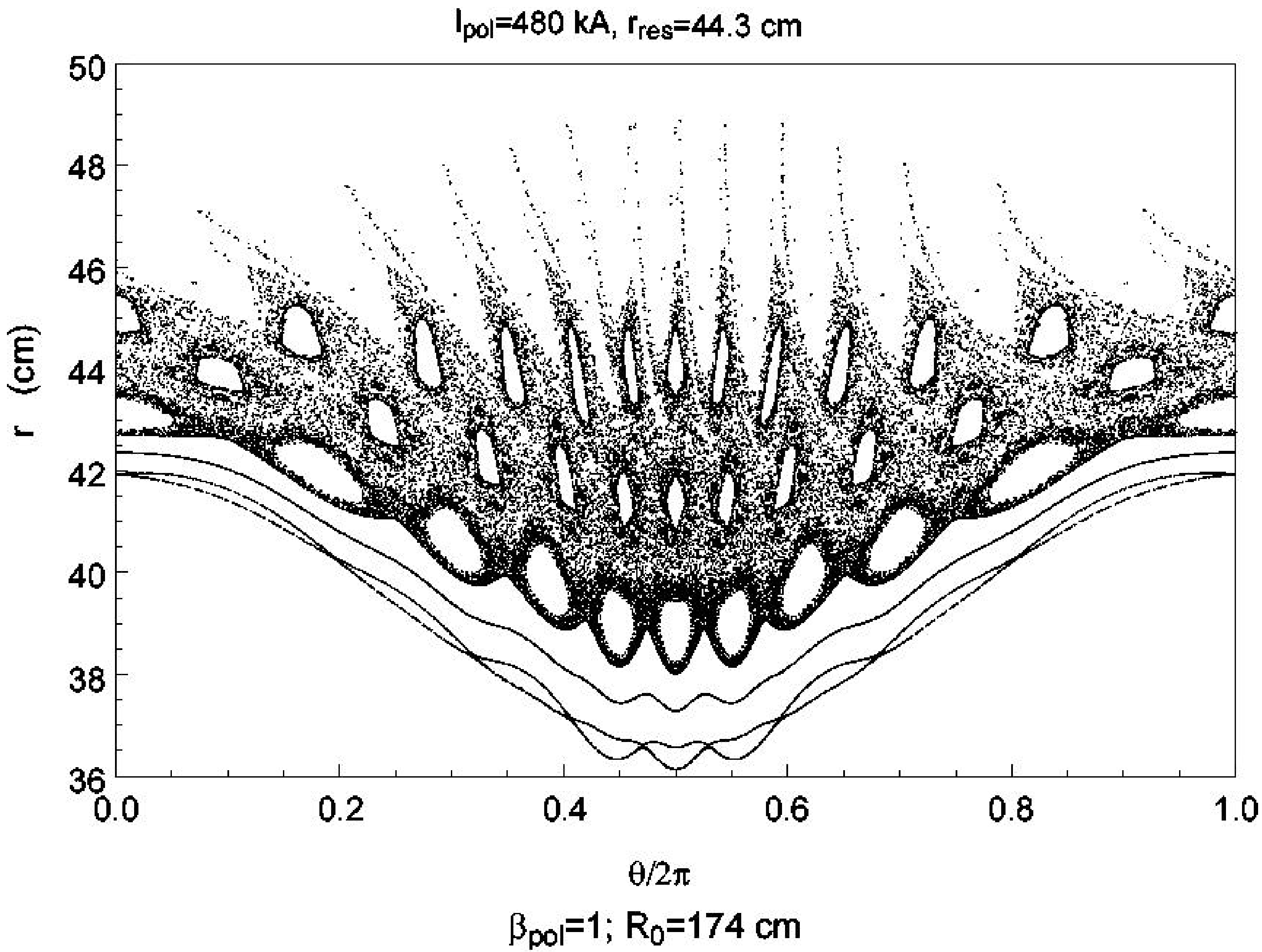
r=0.5 m

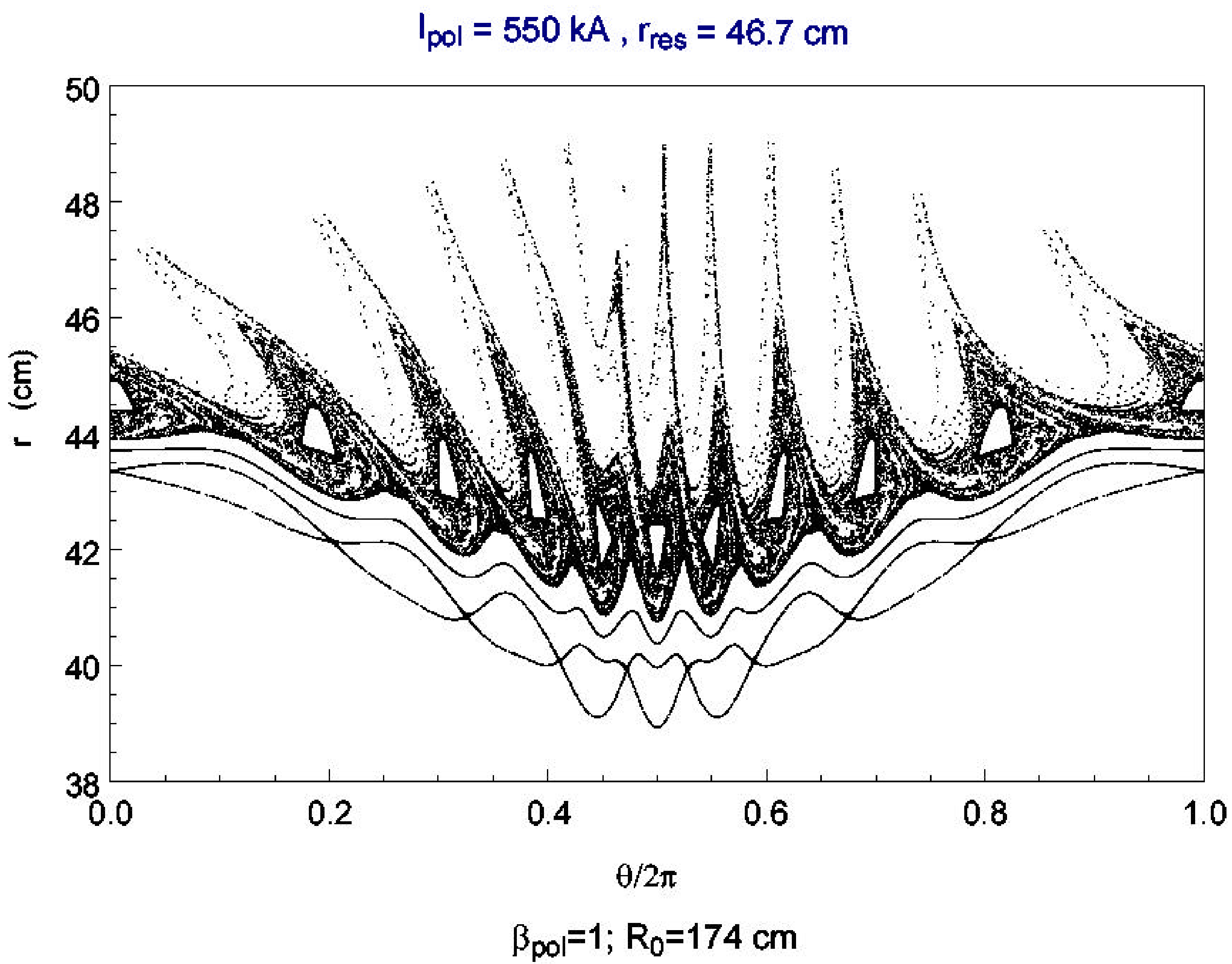


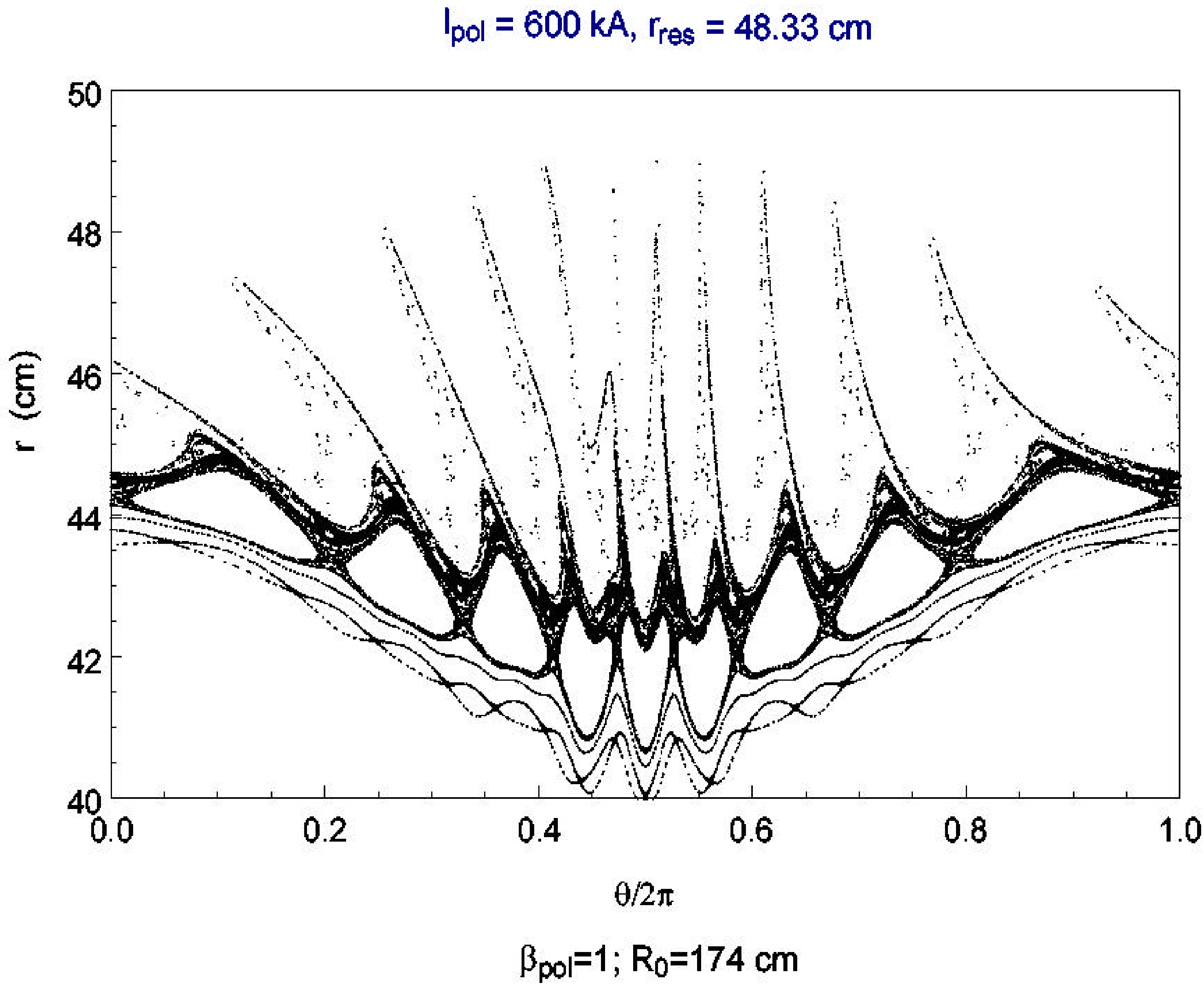
r=0.4 m

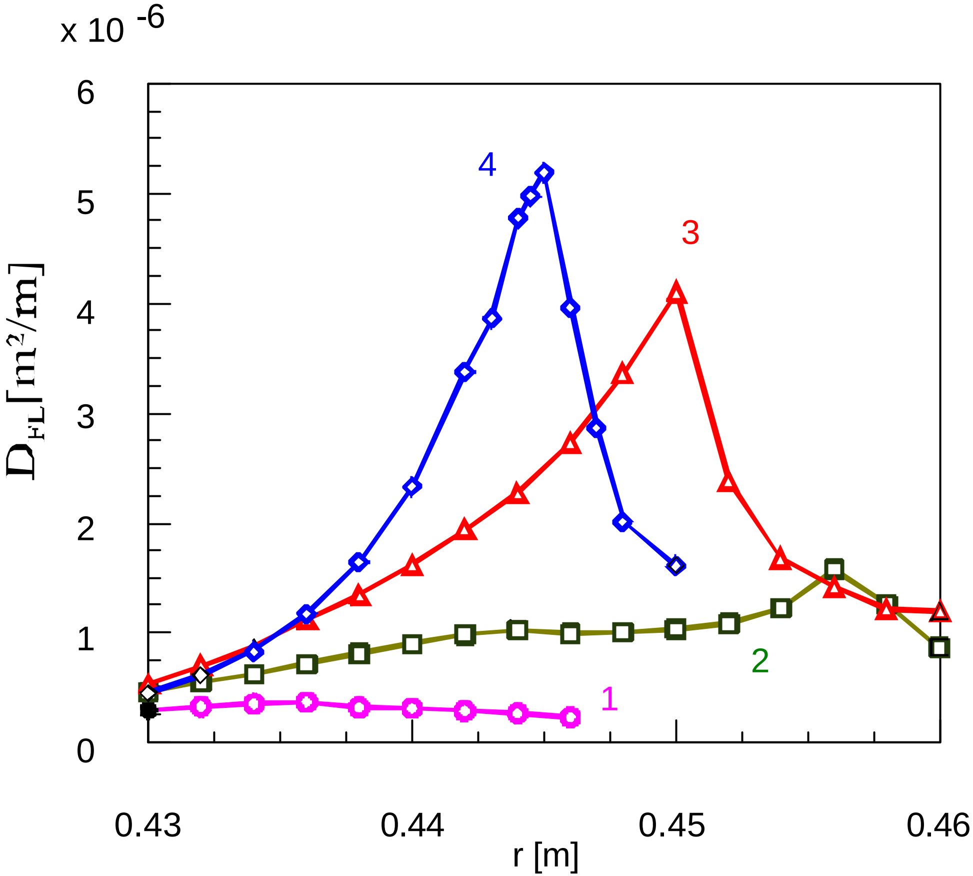
Θ = 360° Θ = 0°

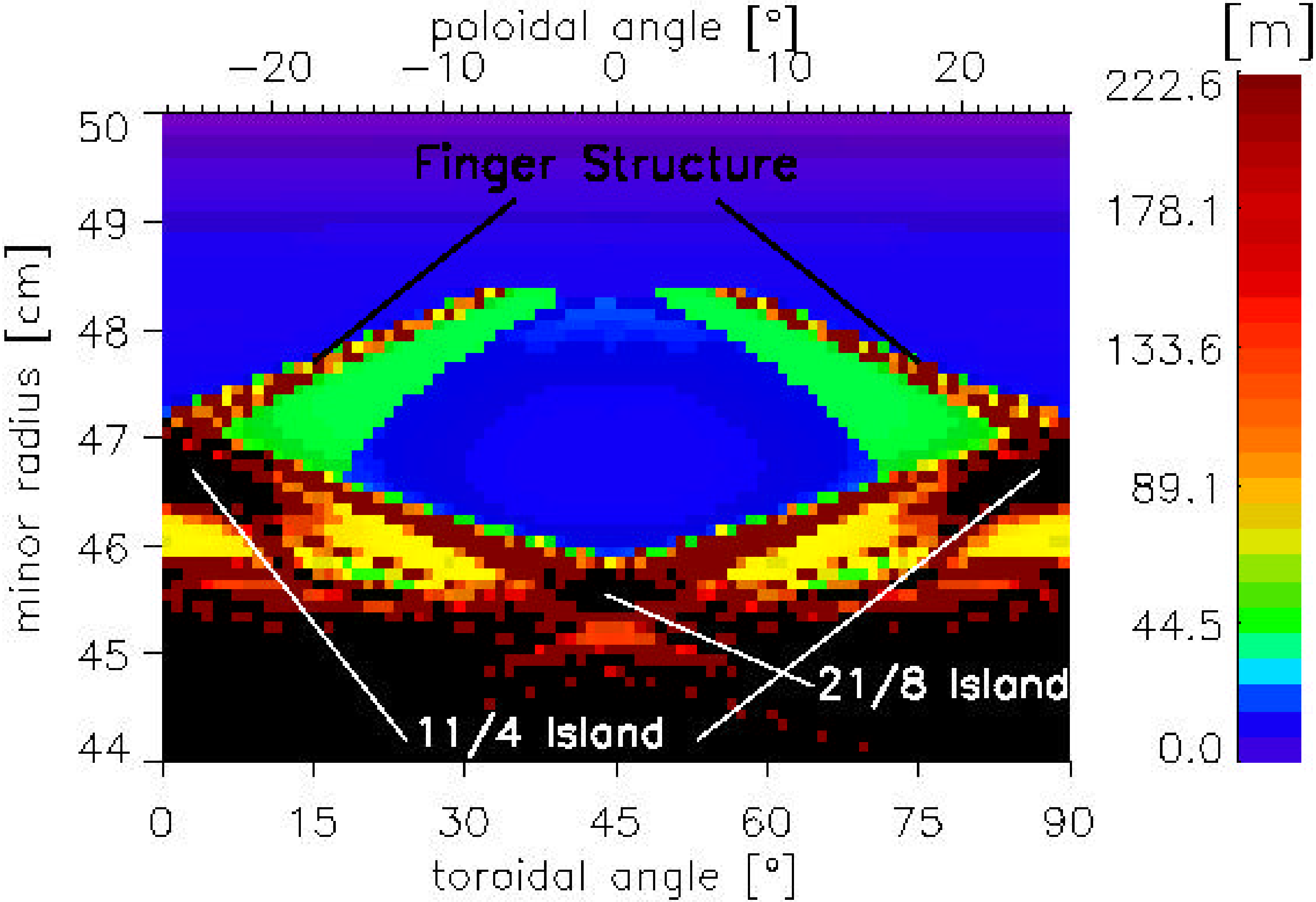
100 % perturbation current

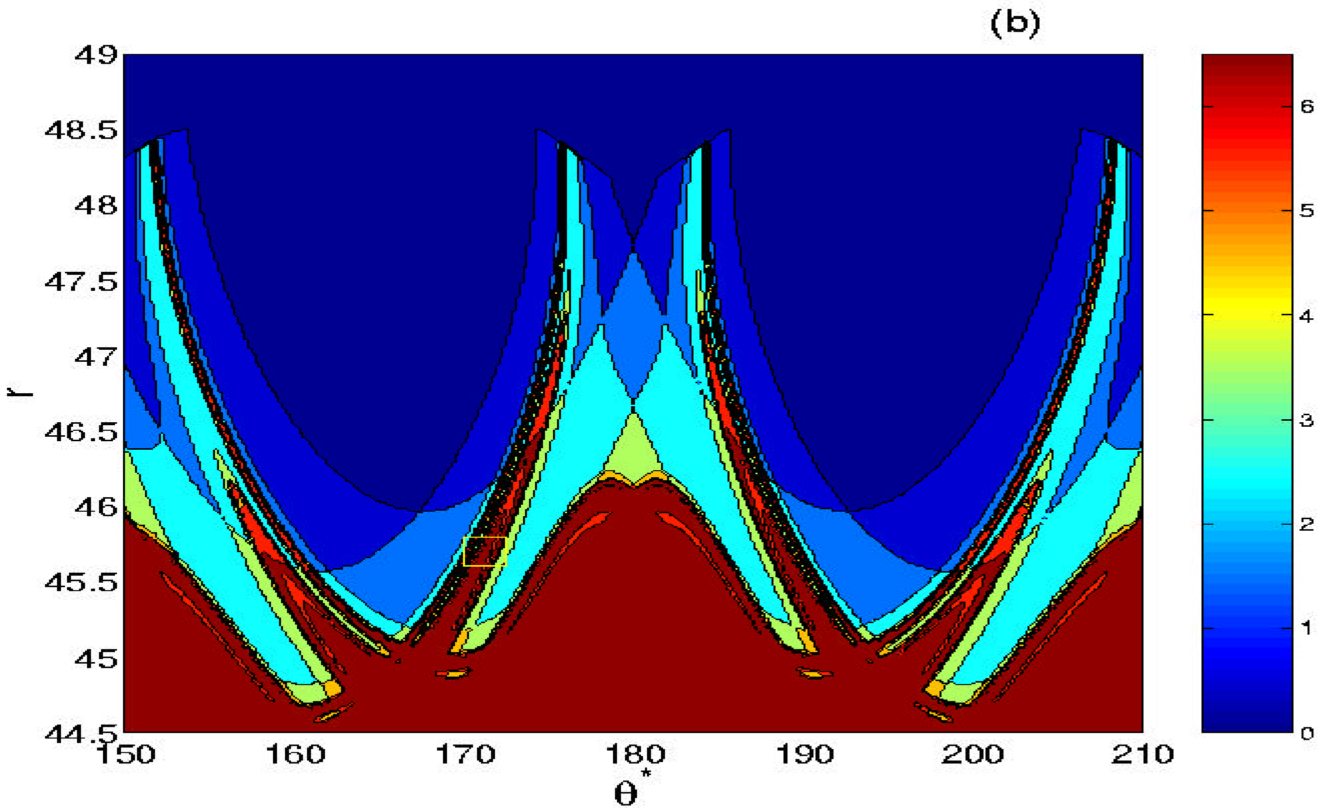

I_{pol}=480 kA, r_{res}=44.3 cm
50
48
46
44
42
40
38
36
r (cm)
0.0
0.2
0.4
0.6
0.8
1.0
θ/2π
β_{pol}=1; R_0=174 cm

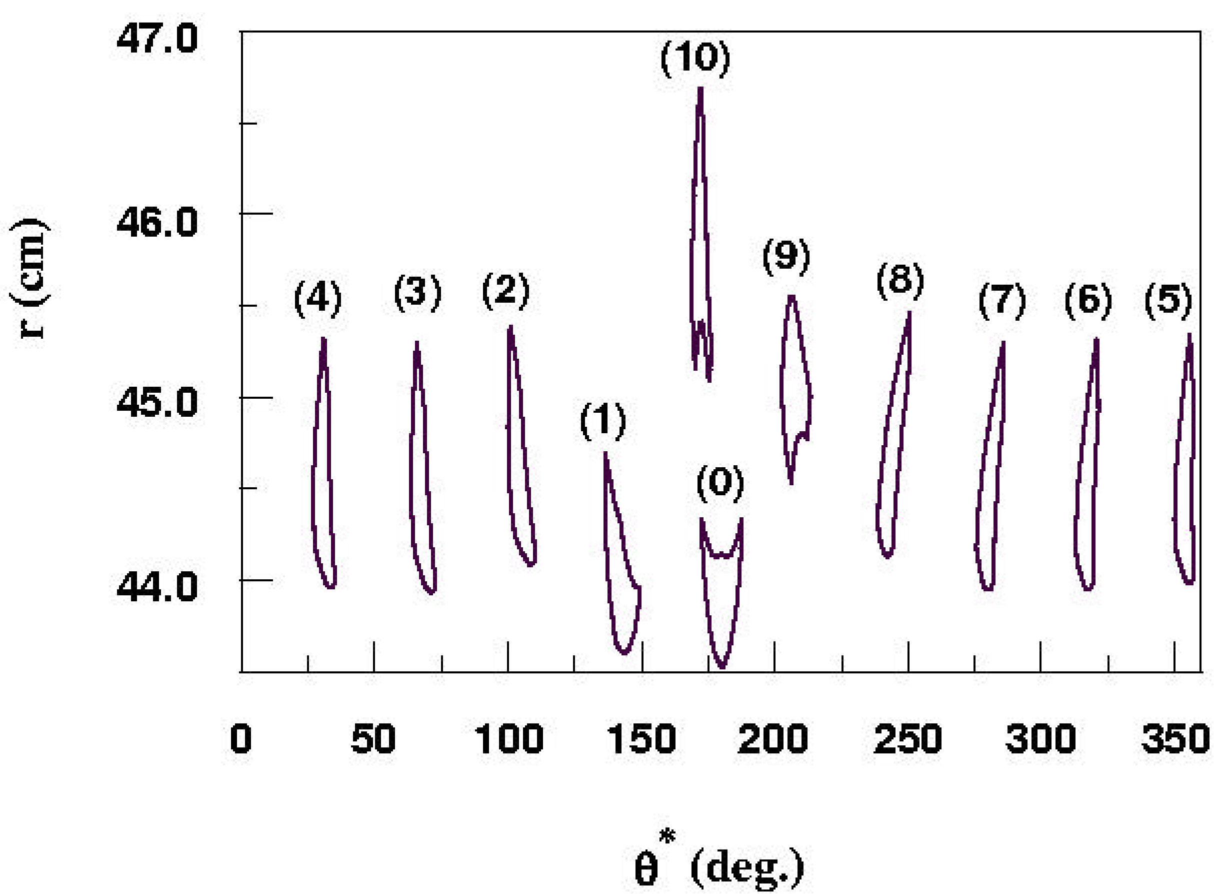

I_{pol} = 550 kA , r_{res} = 46.7 cm
50
48
46
44
42
40
38
r (cm)
0.0
0.2
0.4
0.6
0.8
1.0
θ/2π
β_{pol}=1; R_0=174 cm

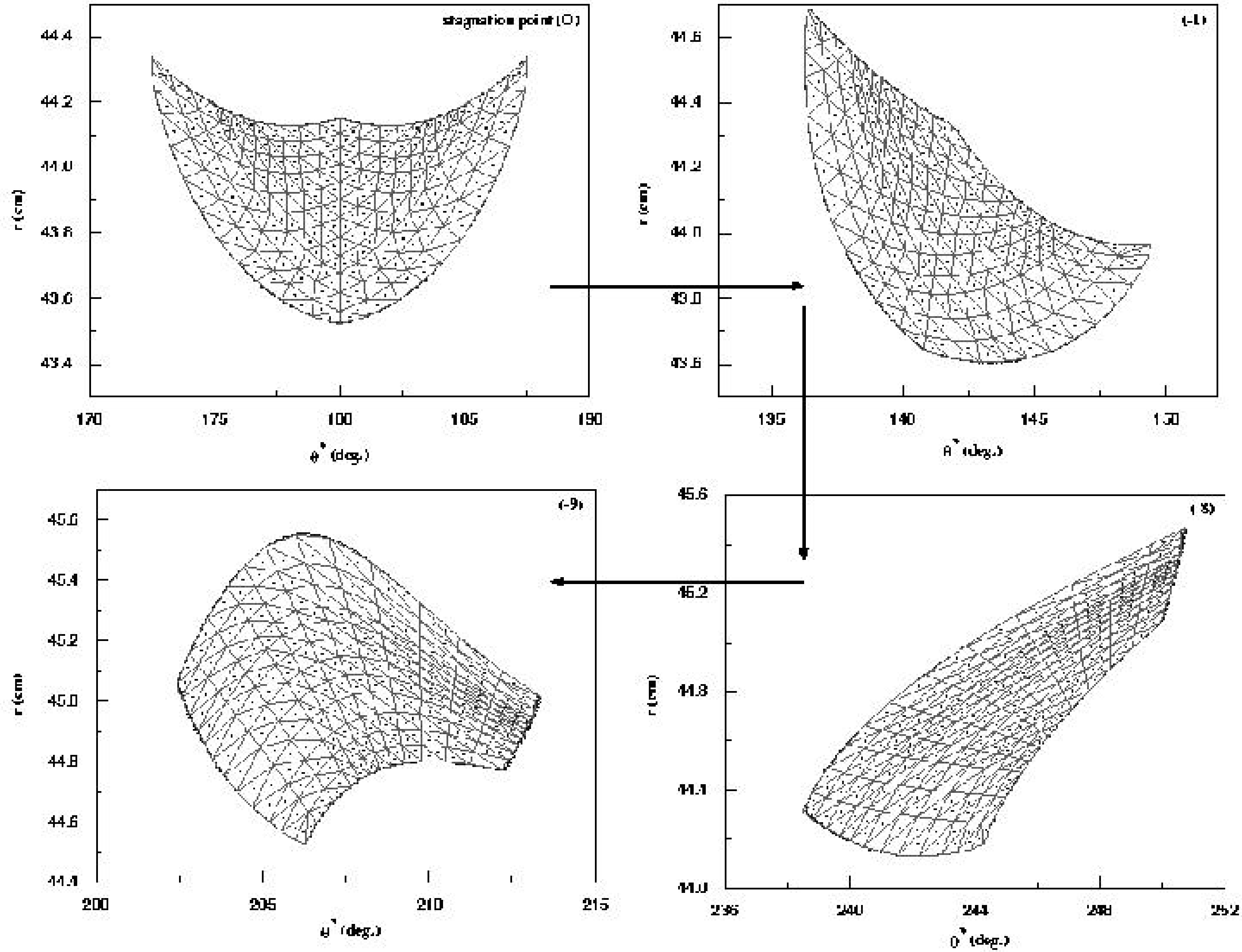

Ipol = 600 kA, rres = 48.33 cm
50
48
46
44
42
40
r (cm)
0.0
0.2
0.4
0.6
0.8
1.0
θ/2π
βpol=1; R0=174 cm

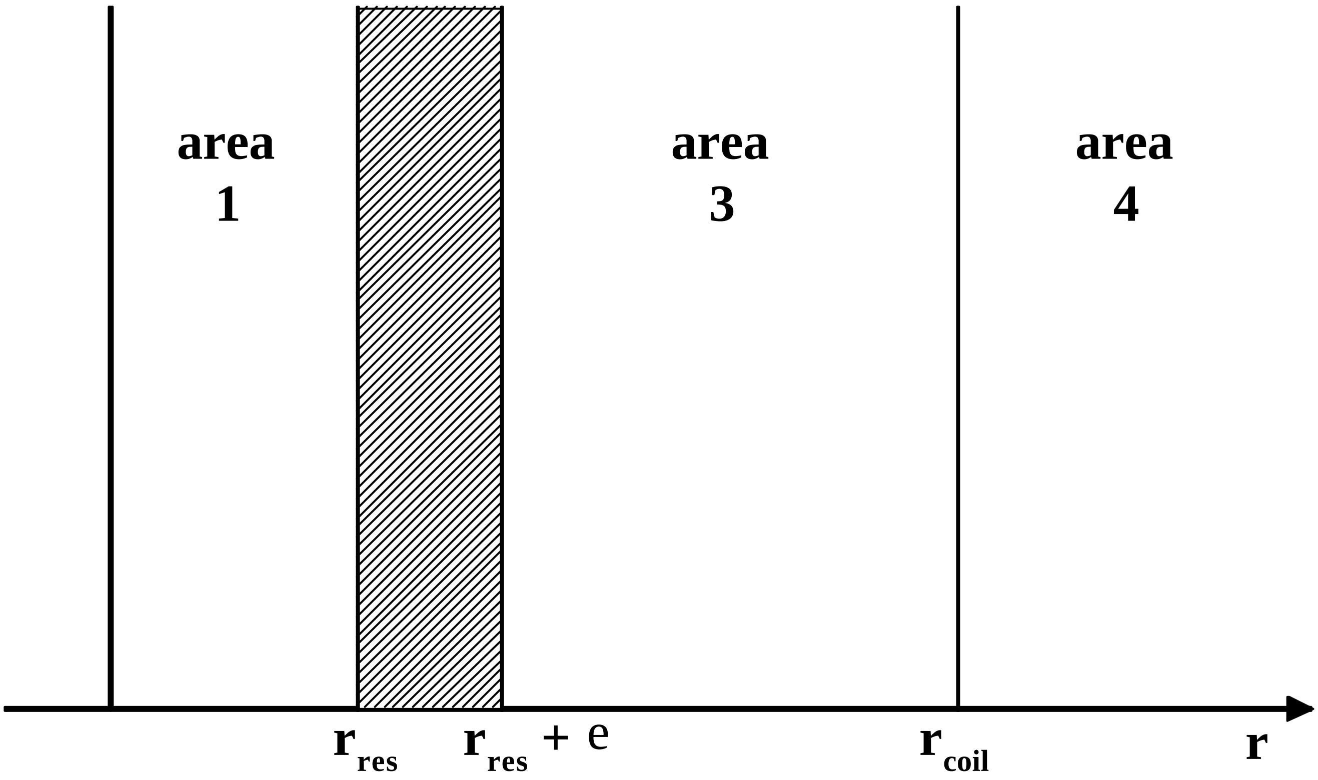

x 10 -6
6
5
4
3
2
1
0
$D_{FL}\,[m^2/m]$
4
3
2
1
0.43
0.44
0.45
0.46
r [m]

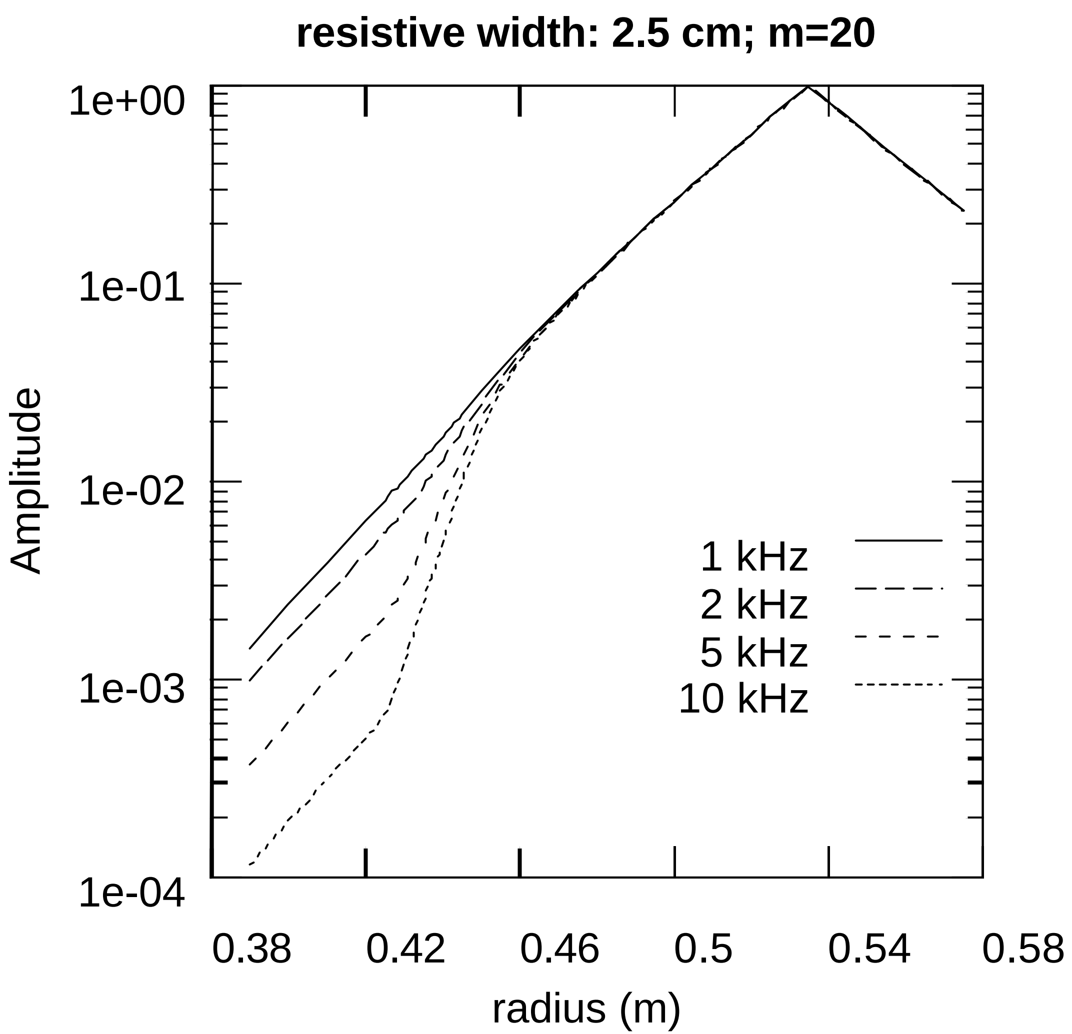

poloidal angle [°]
−20
−10
0
10
20
[m]
222.6
178.1
133.6
89.1
44.5
0.0
50
49
48
47
46
45
44
minor radius [cm]
Finger Structure
11/4 Island
21/8 Island
0
15
30
45
60
75
90
toroidal angle [°]

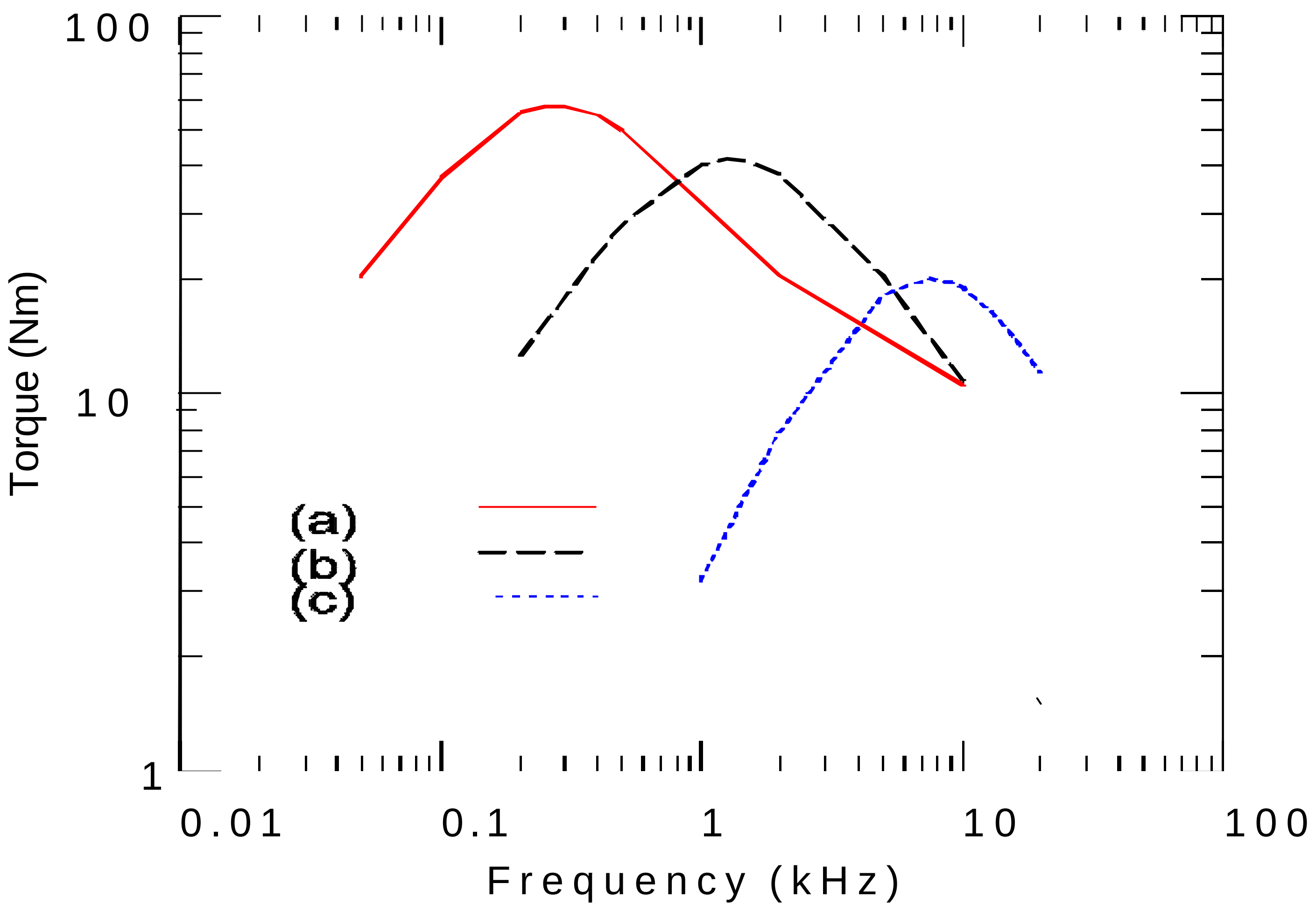

(b)
49
48.5
48
47.5
47
46.5
46
45.5
45
44.5
r
150
160
170
180
190
200
210
θ*
0
1
2
3
4
5
6


47.0
46.0
45.0
44.0
r (cm)
(10)
(9)
(8)
(7)
(6)
(5)
(4)
(3)
(2)
(1)
(0)
0
50
100
150
200
250
300
350
θ* (deg.)


stagnation point (O)
r (cm)


area
1
area
3
area
4
r res
r res + e
r coil
r


resistive width: 2.5 cm; m=20
Amplitude
1e+00
1e-01
1e-02
1e-03
1e-04
0.38
0.42
0.46
0.5
0.54
0.58
radius (m)
1 kHz
2 kHz
5 kHz
10 kHz


100
10
1
Torque (Nm)
0.01
0.1
1
10
100
Frequency (kHz)
(a)
(b)
(c)

Summary

The DED-coils are continuous helical windings located at the HFS inside the vessel.

The Dynamic ergodic divertor will most likely provide a sufficient ergodization level at the plasma edge.

A laminar zone will form the main contact region with the wall; a 2D and 3D modeling was successful.

The field rotation imposes a torque at the plasma edge which is probably sufficient for generating a differential plasma rotation.

The differential rotation may lead to a suppression of turbulence and an improvement of the confinement; locked modes should be acceterated again.