RIGA DYNAMO EXPERIMENT

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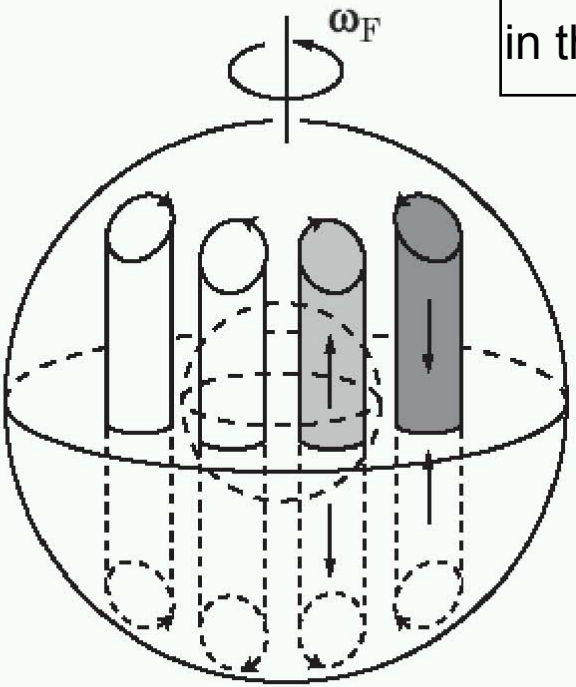
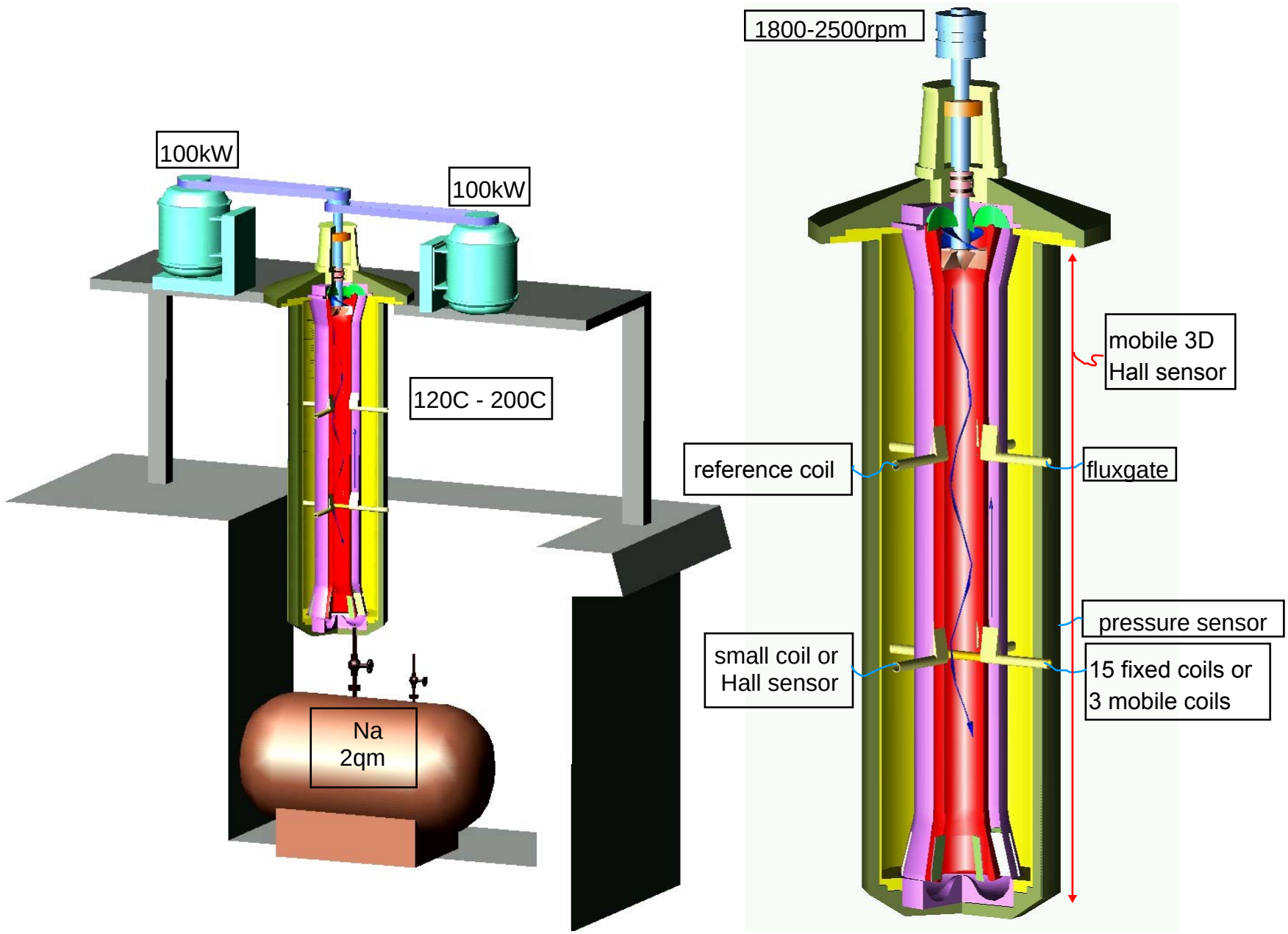
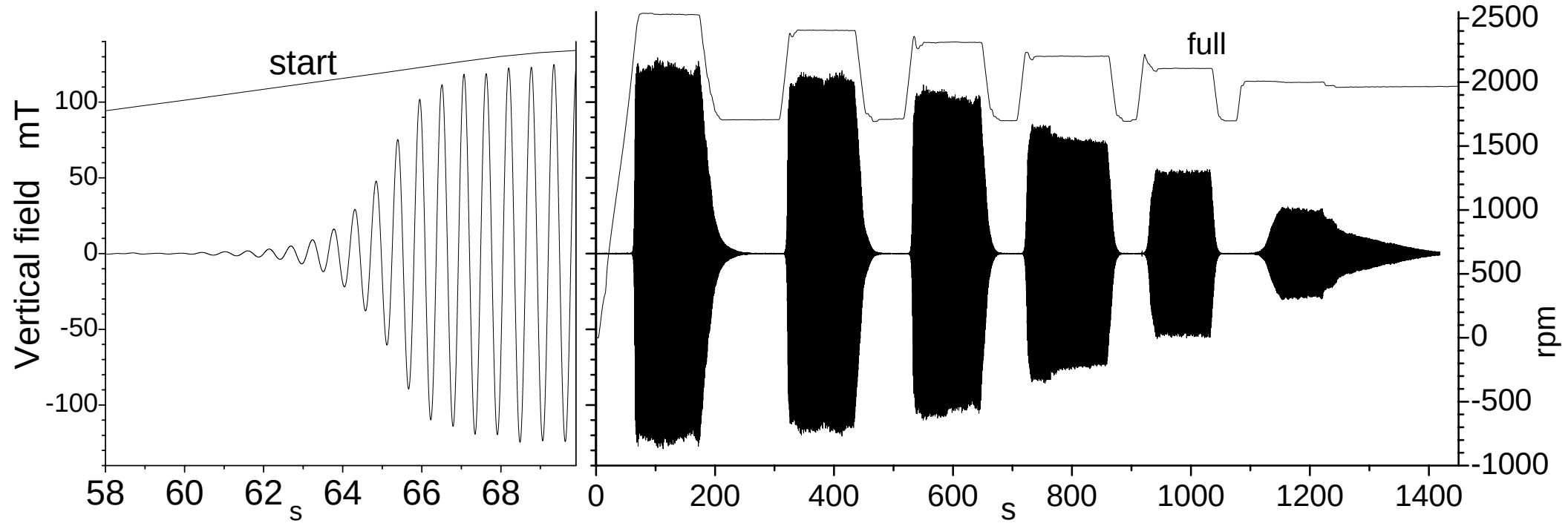
G.Gerbeth & F.Stefani

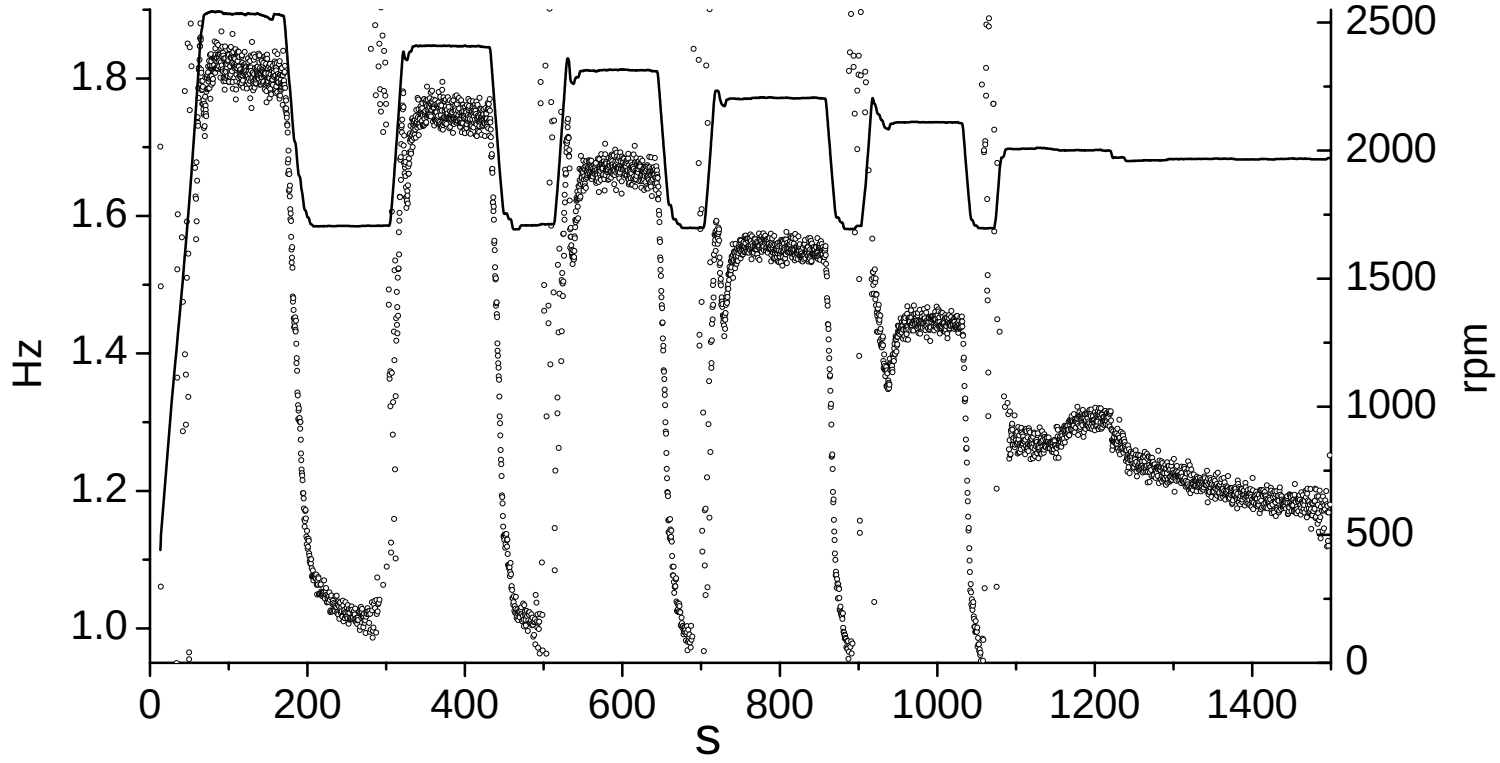
Convection columns in the Earth core

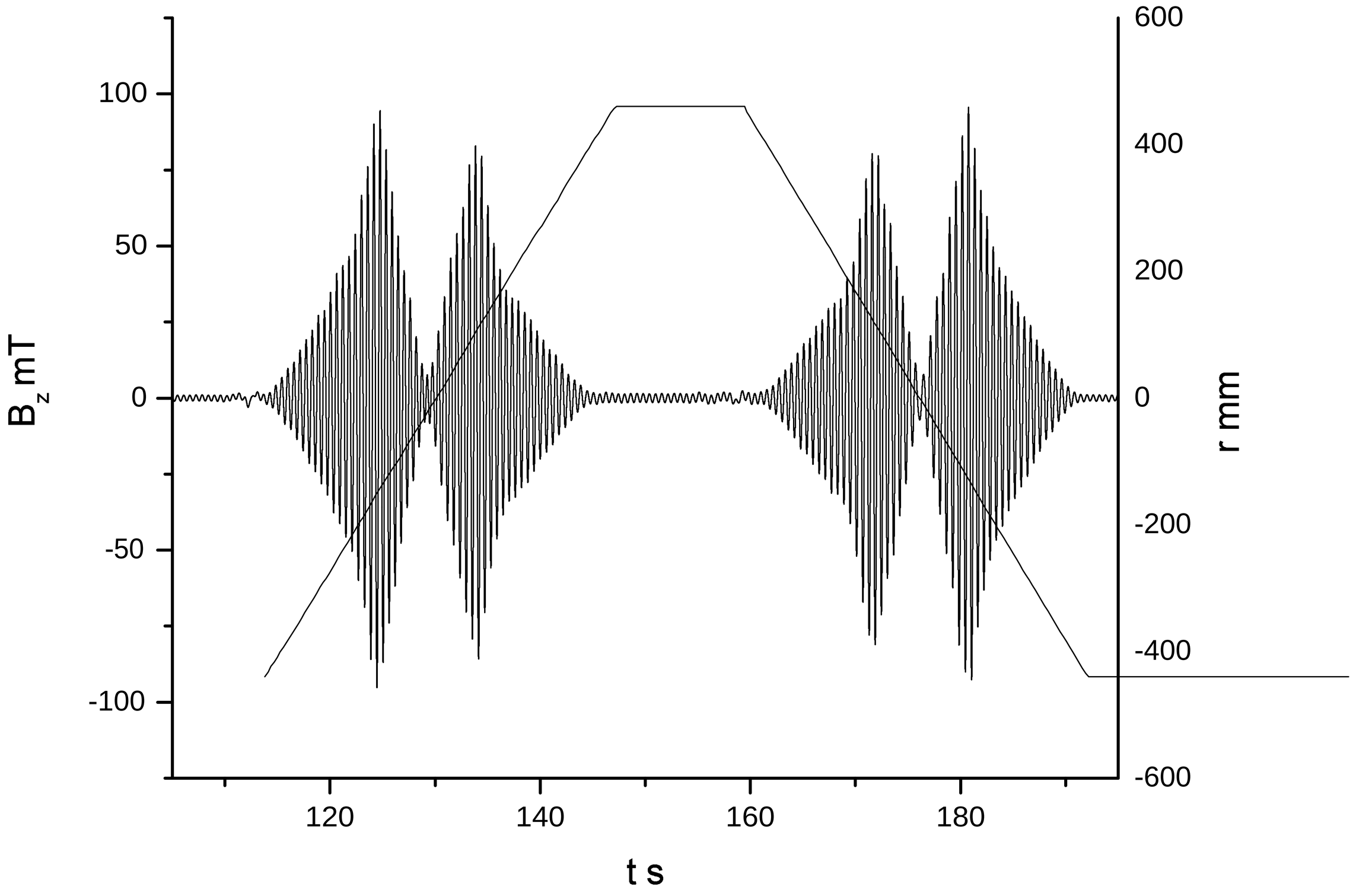




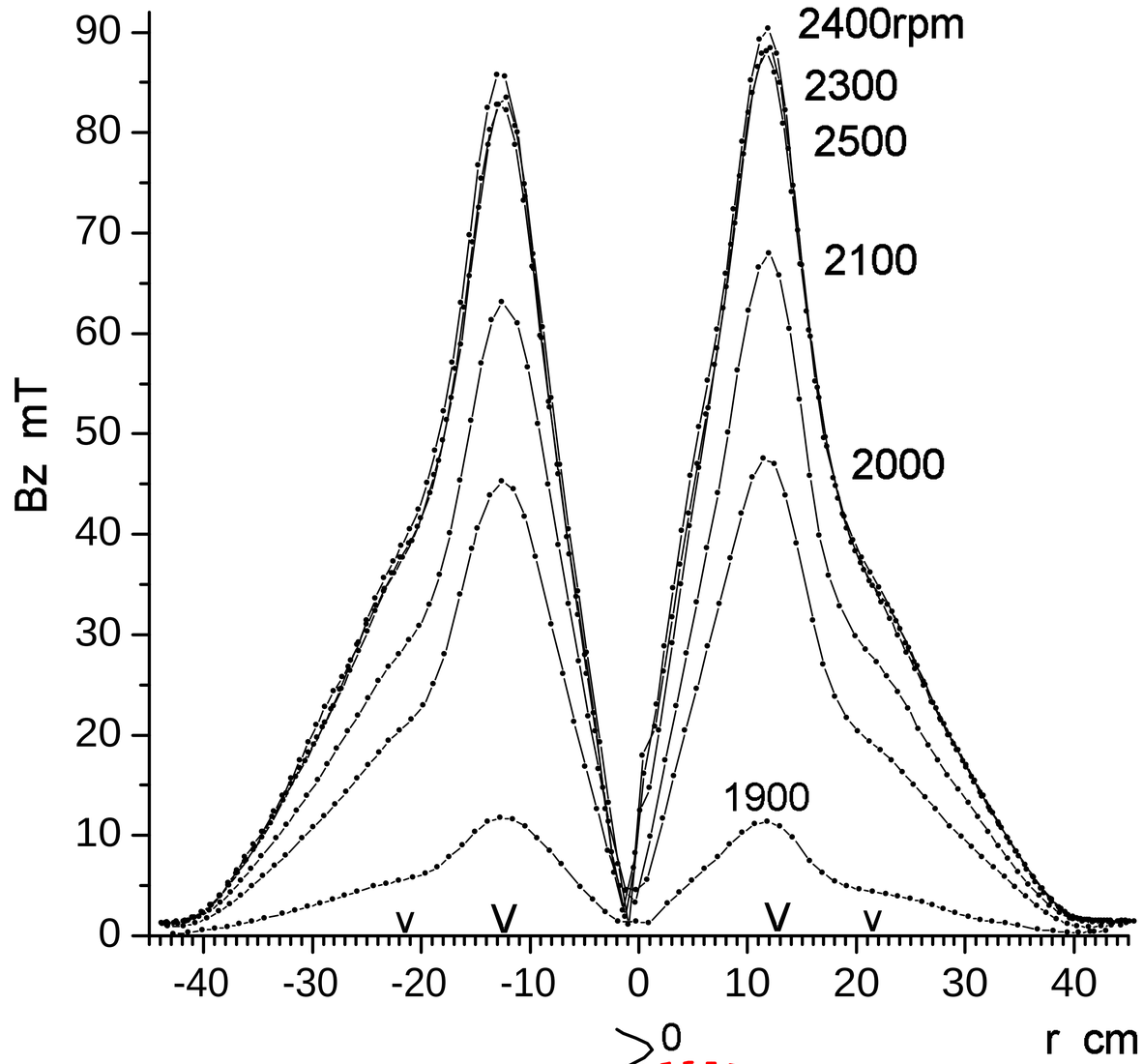
Experiment setup

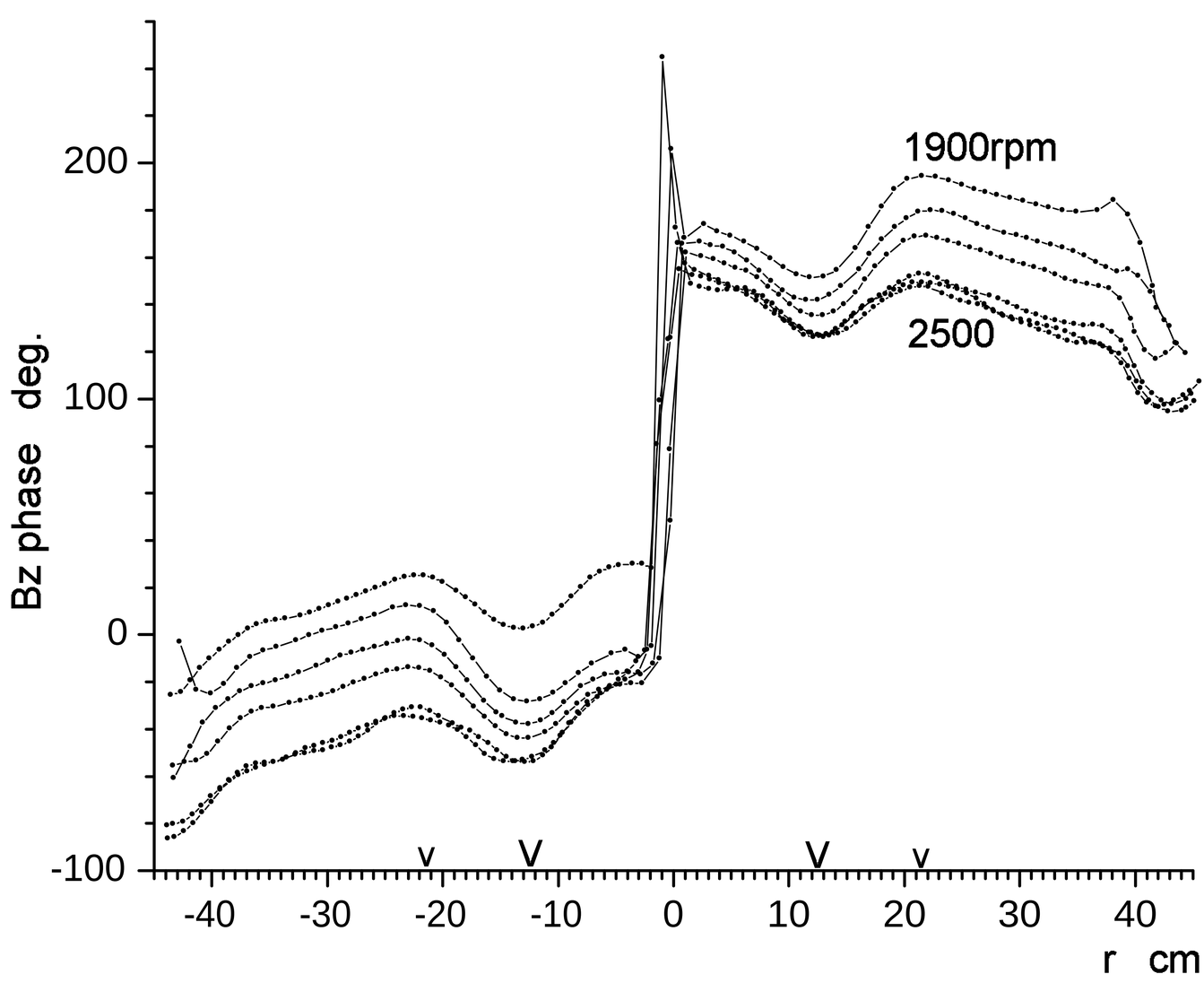

start
full
Vertical field mT
100
50
0
-50
-100
58
60
62
64
66
68
s
0
200
400
600
800
1000
1200
1400
s
2500
2000
1500
1000
500
0
-500
-1000
rpm

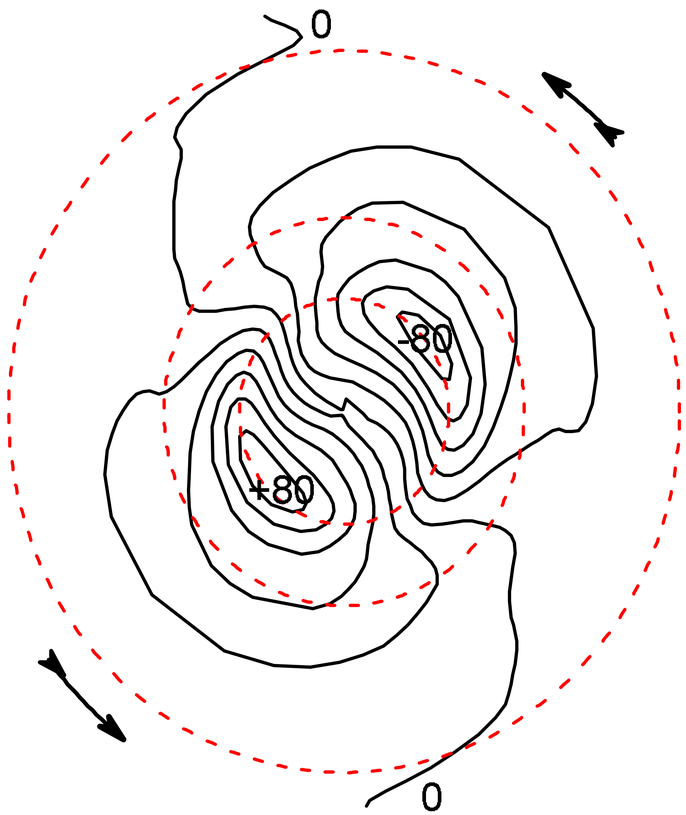

Hz
1.8
1.6
1.4
1.2
1.0
0
200
400
600
800
1000
1200
1400
s
2500
2000
1500
1000
500
0
rpm

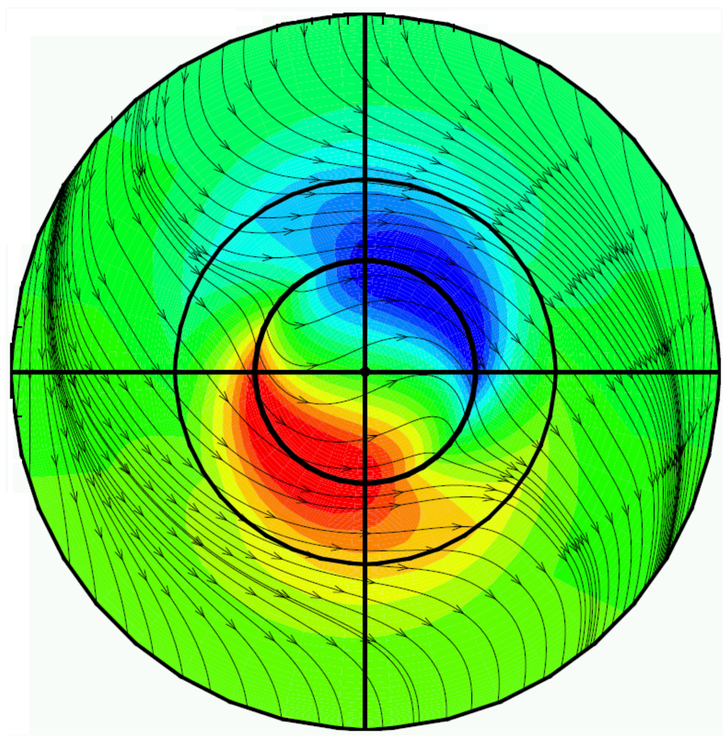

100
50
0
-50
-100
B_z mT
600
400
200
0
-200
-400
-600
r mm
120
140
160
180
t s

VERTICAL FIELD

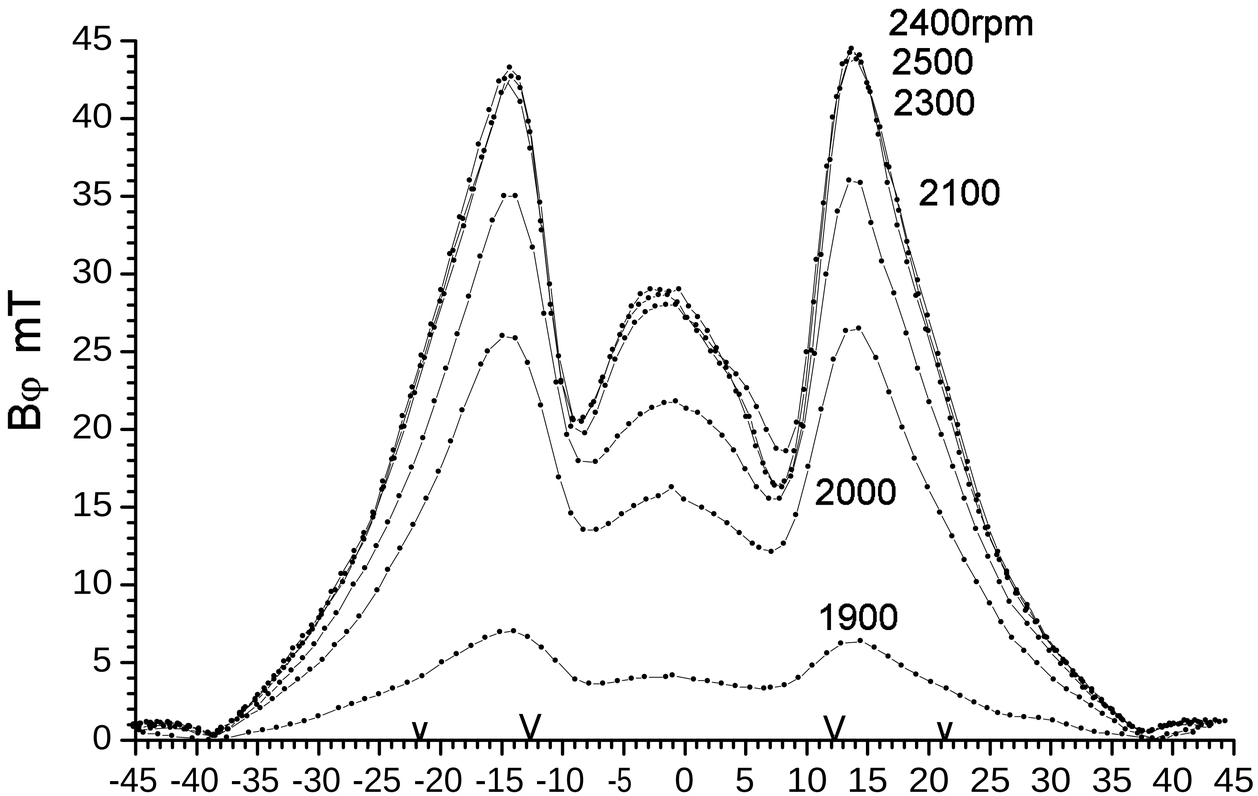


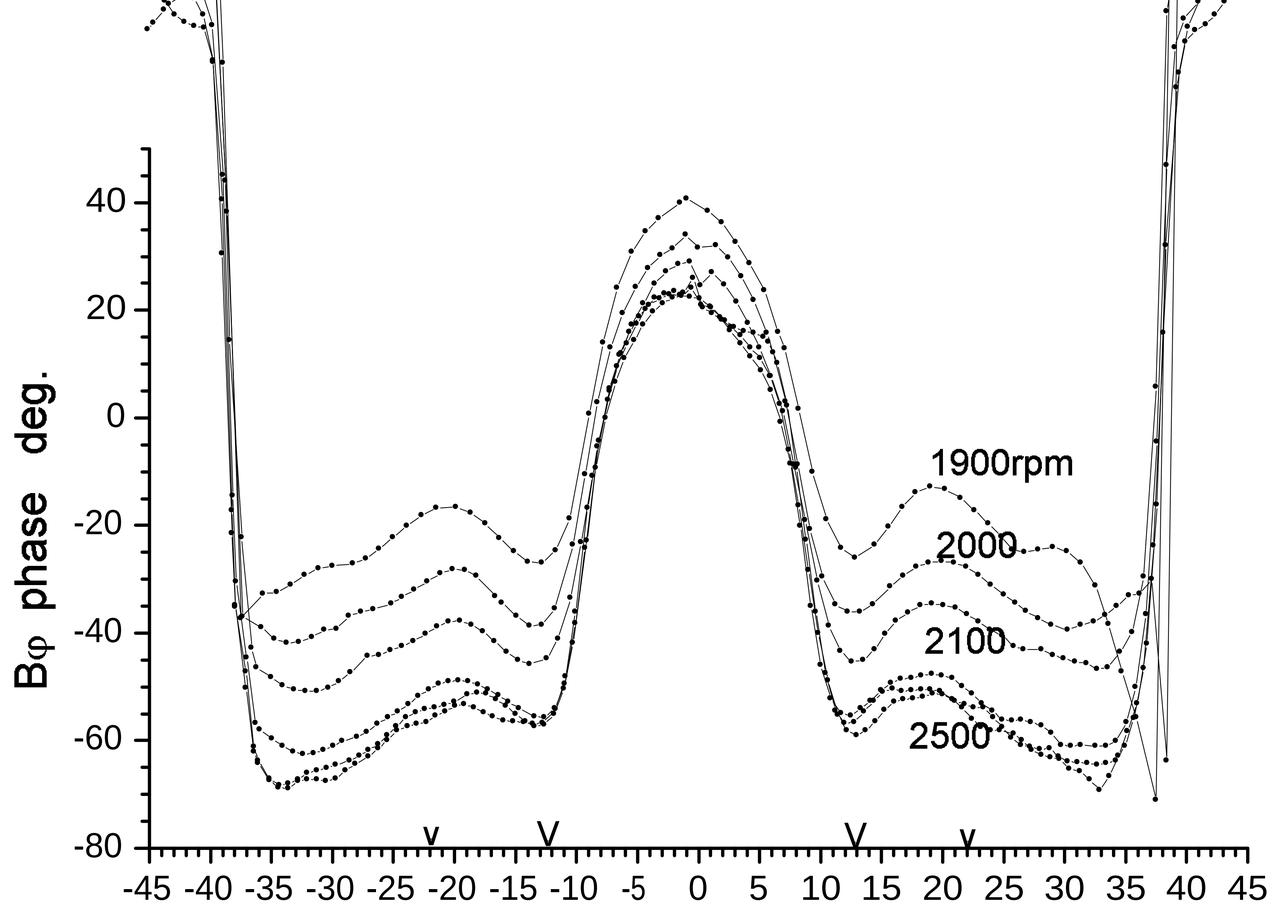


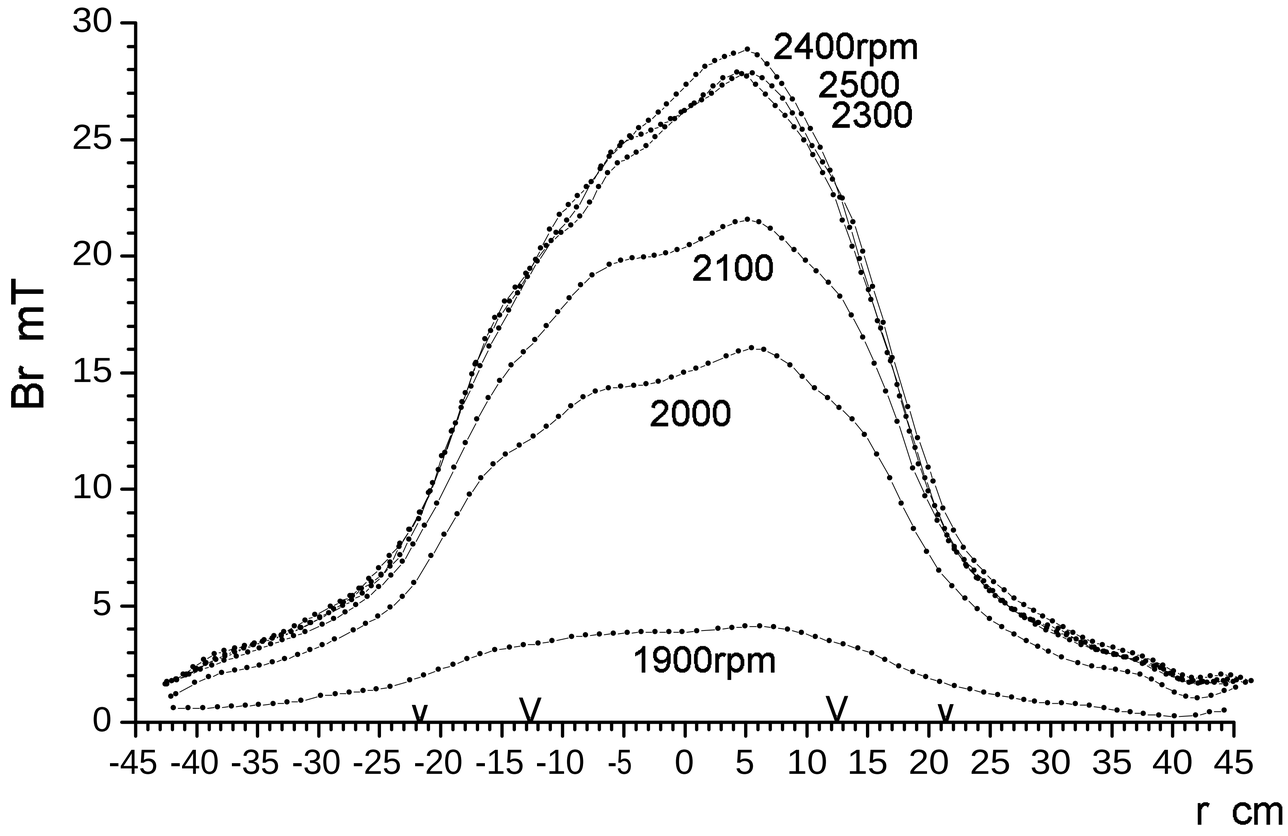


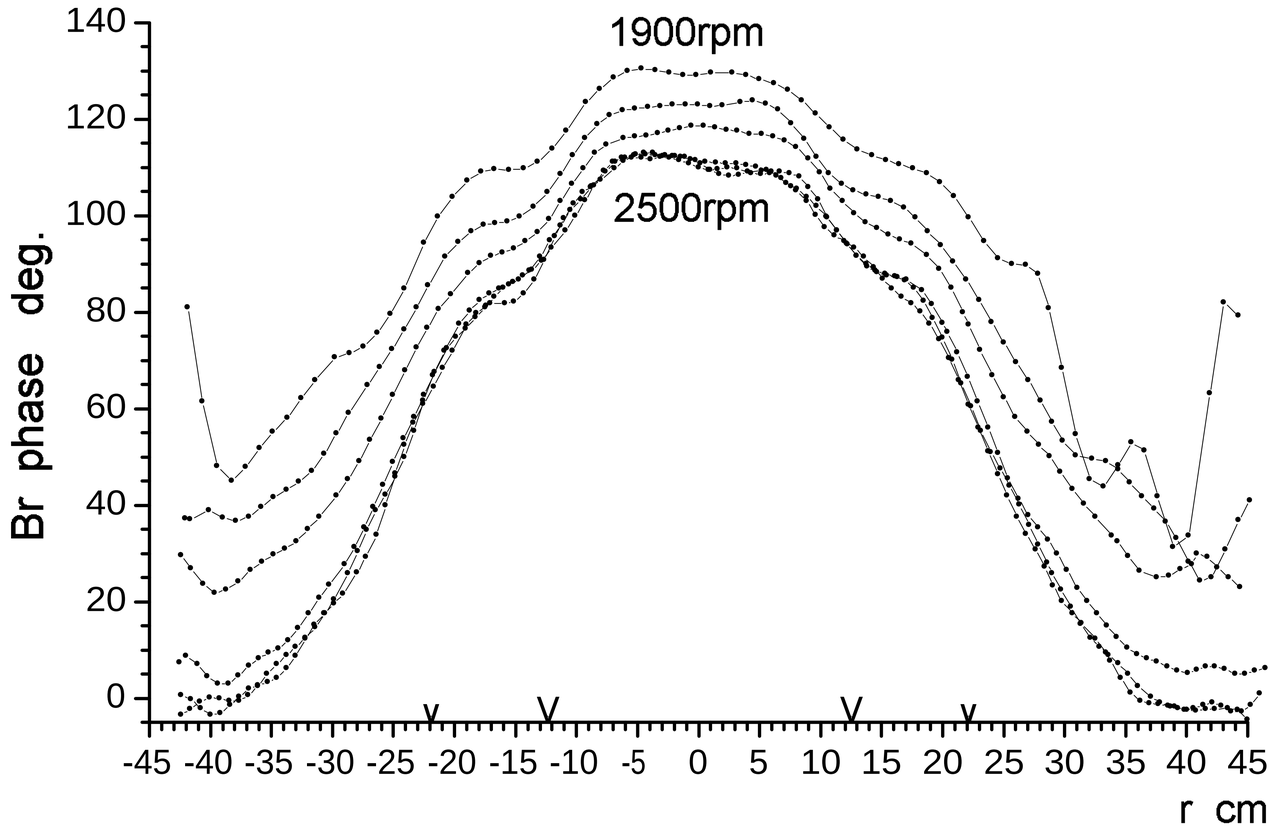


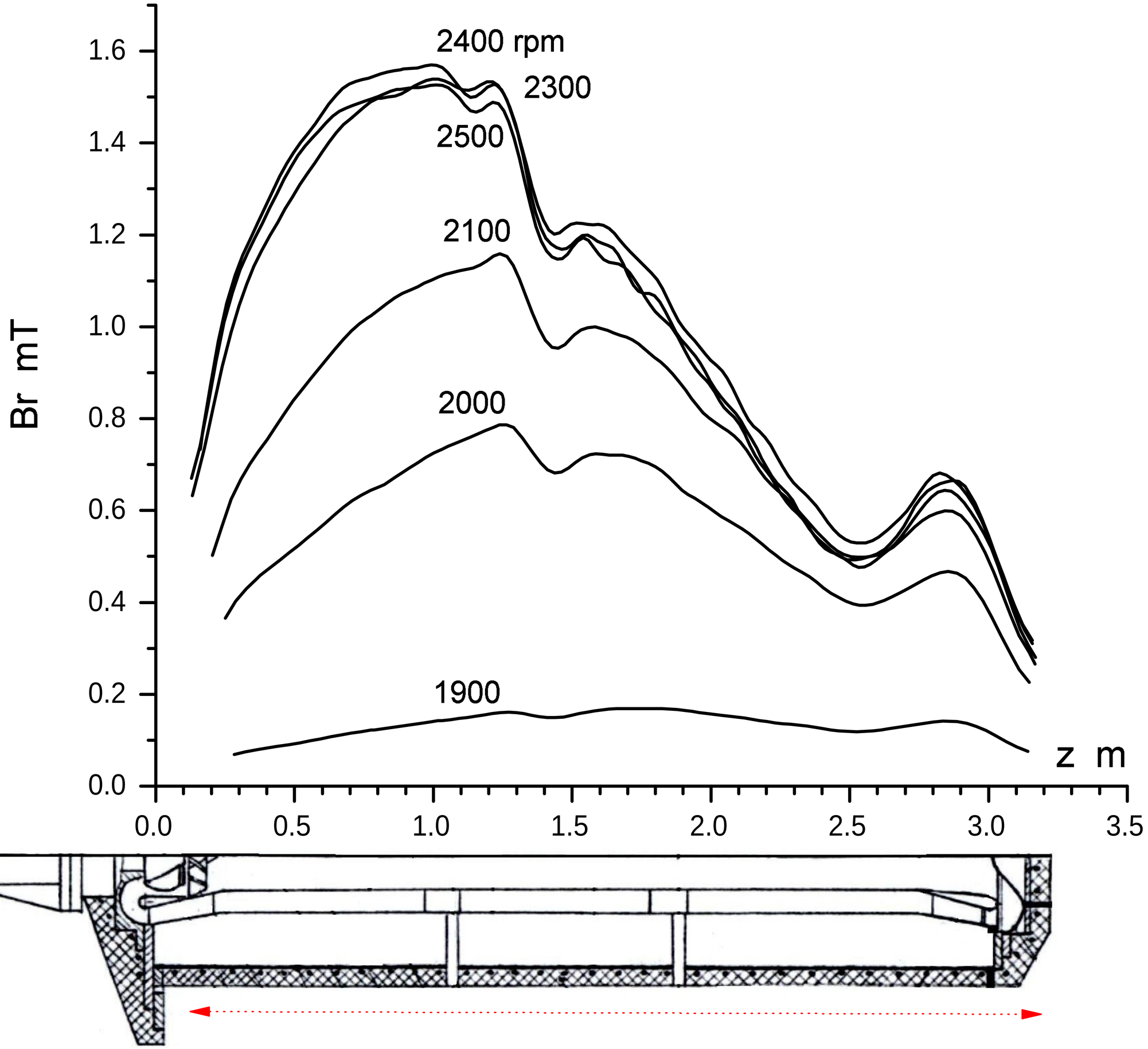
Horizontal field

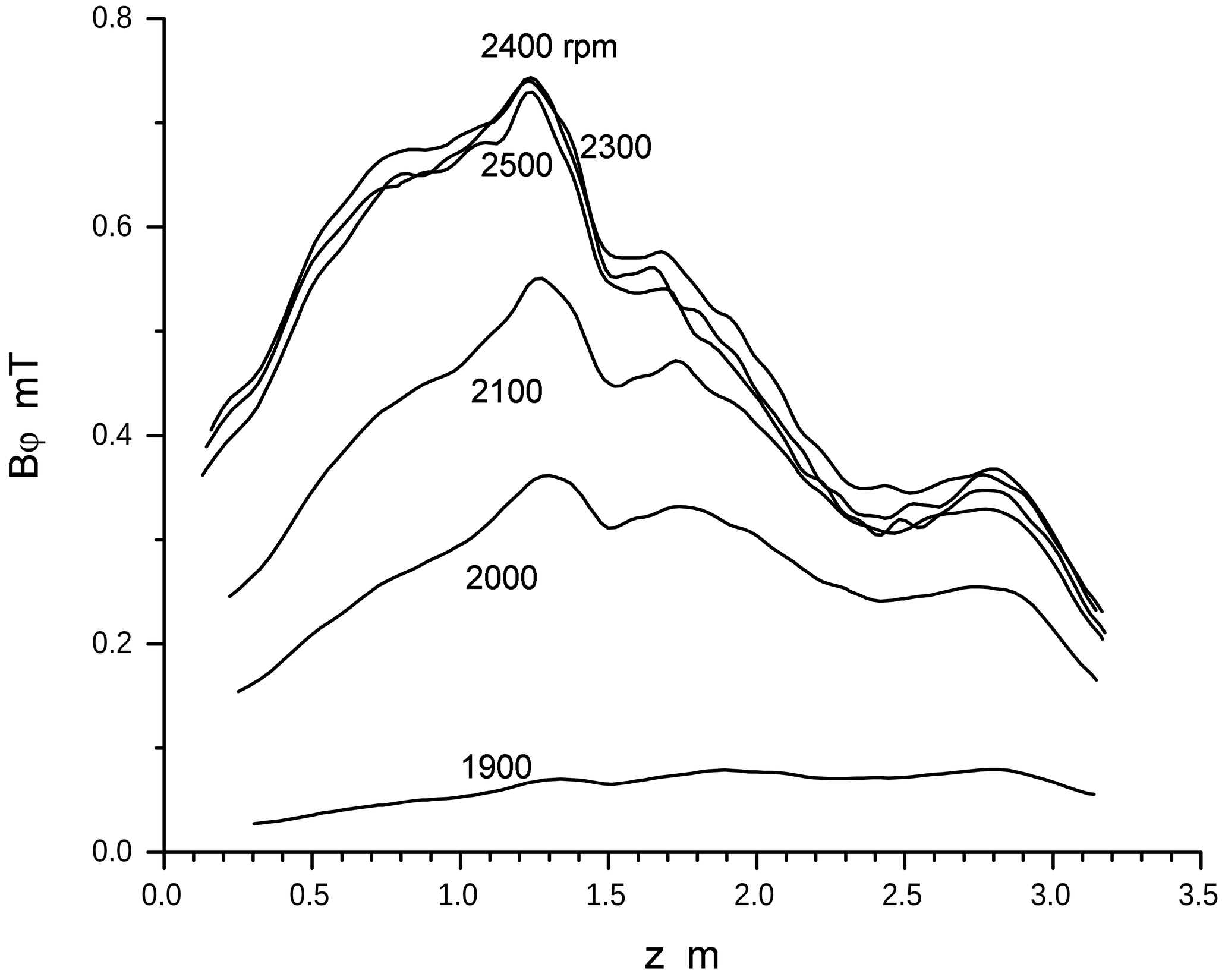


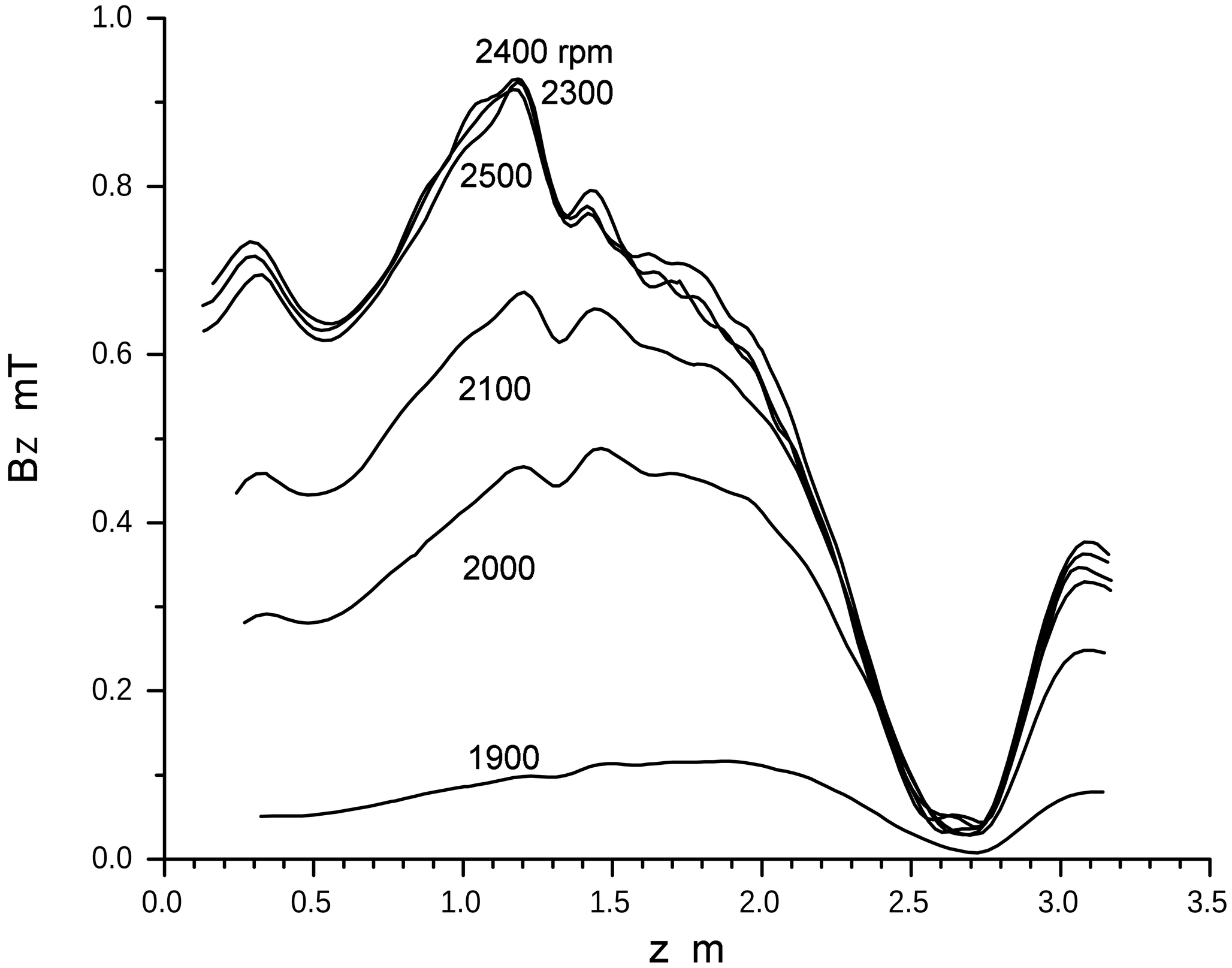


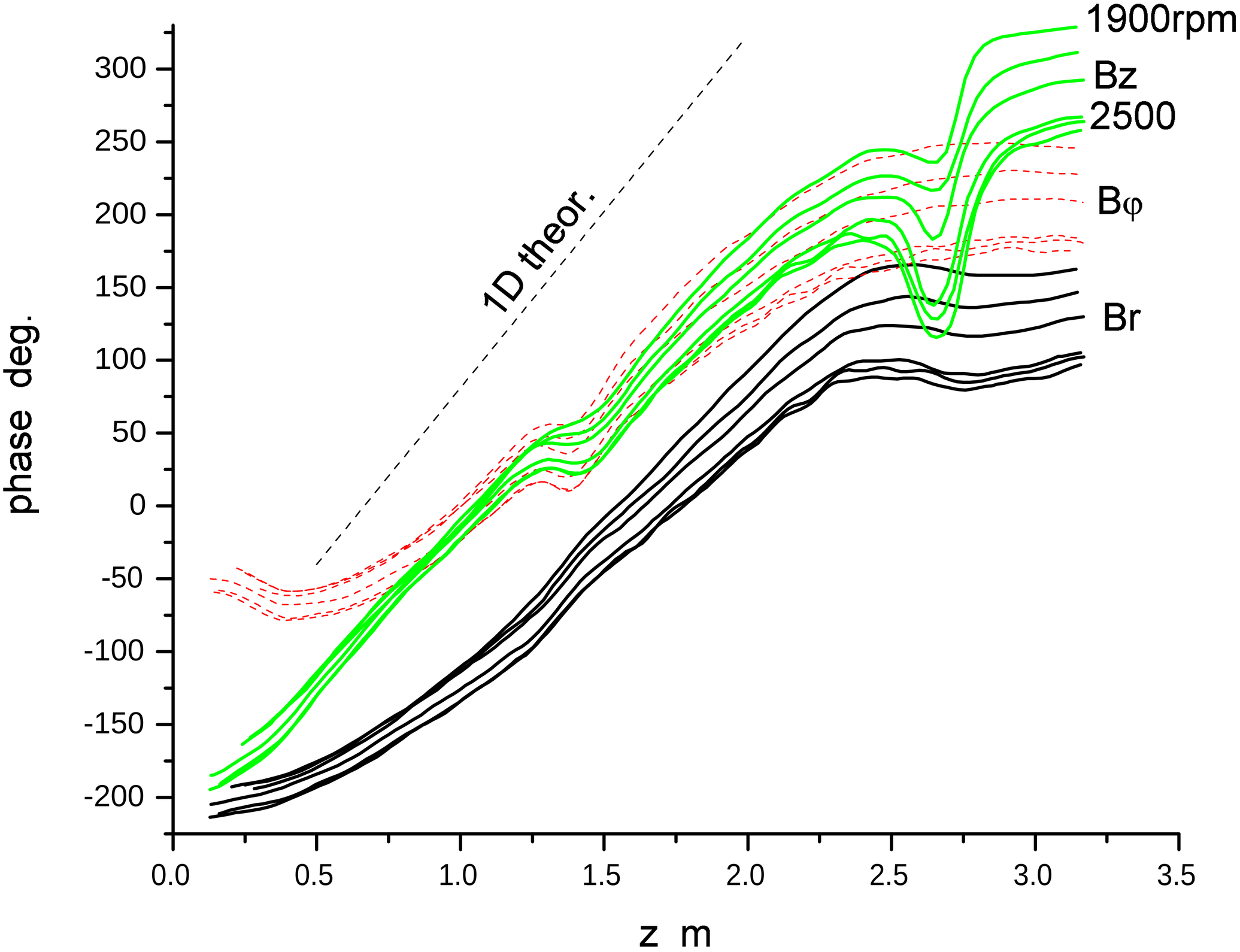


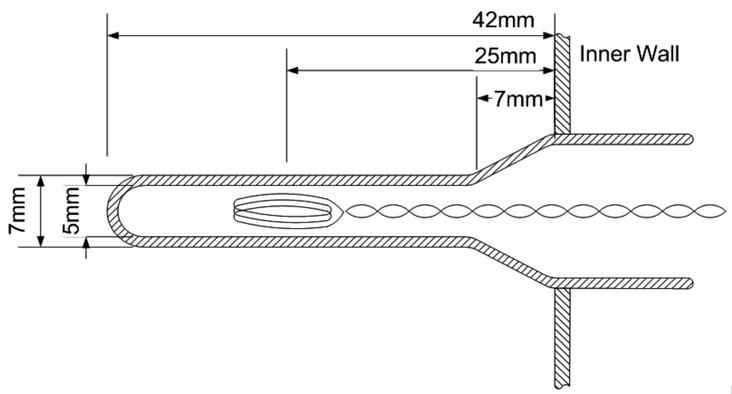


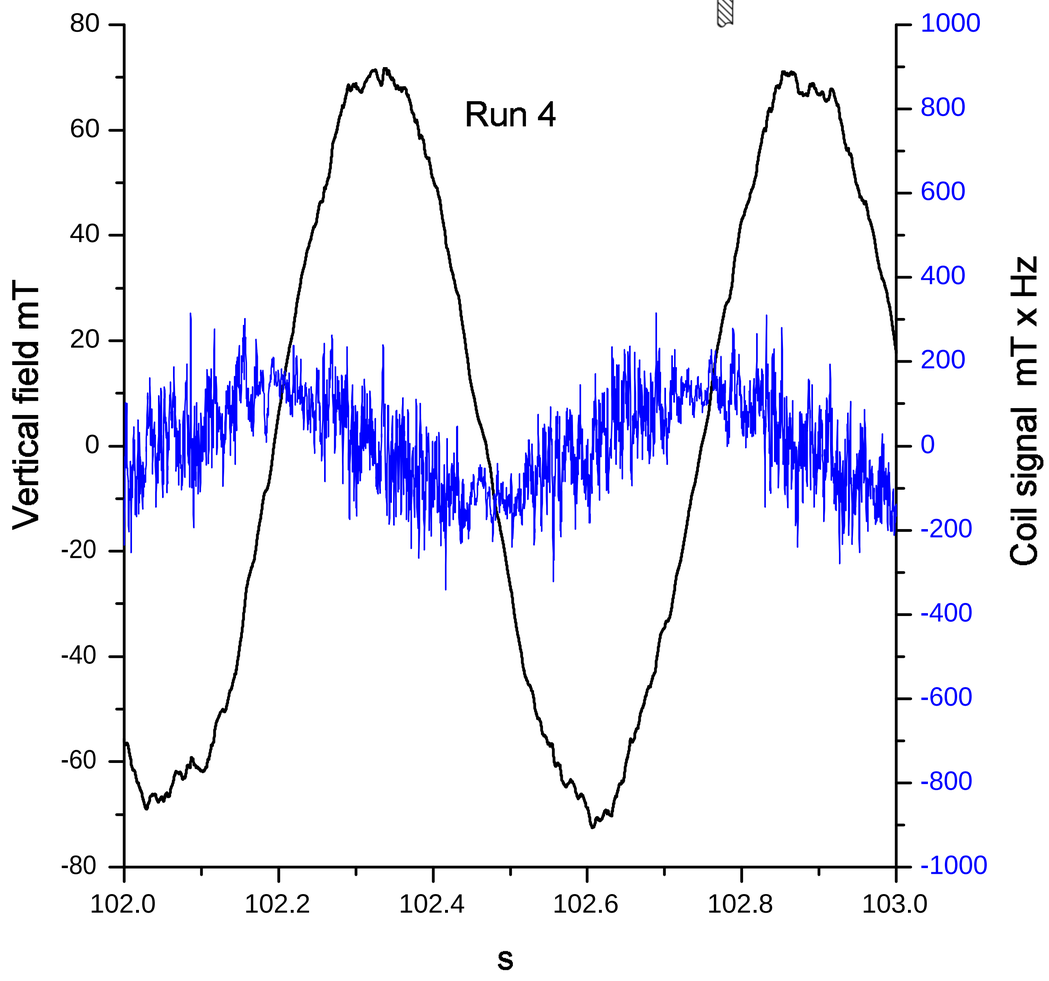

2400 rpm
2300
2500
2100
2000
1900
Br mT
z m
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

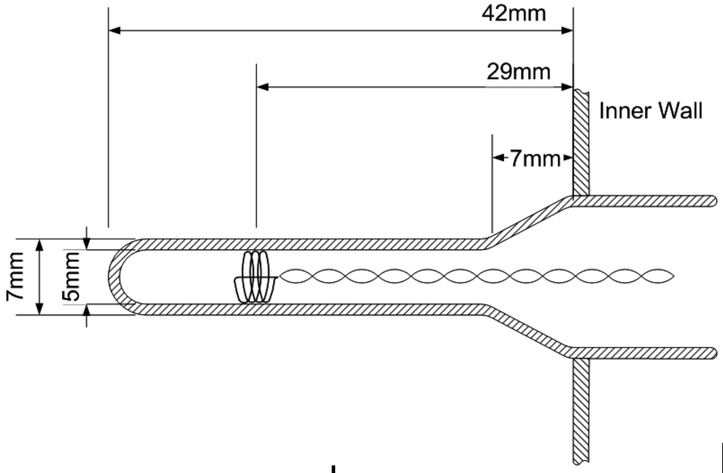

0.8
0.6
0.4
0.2
0.0
Bφ mT
2400 rpm
2300
2500
2100
2000
1900
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
z m

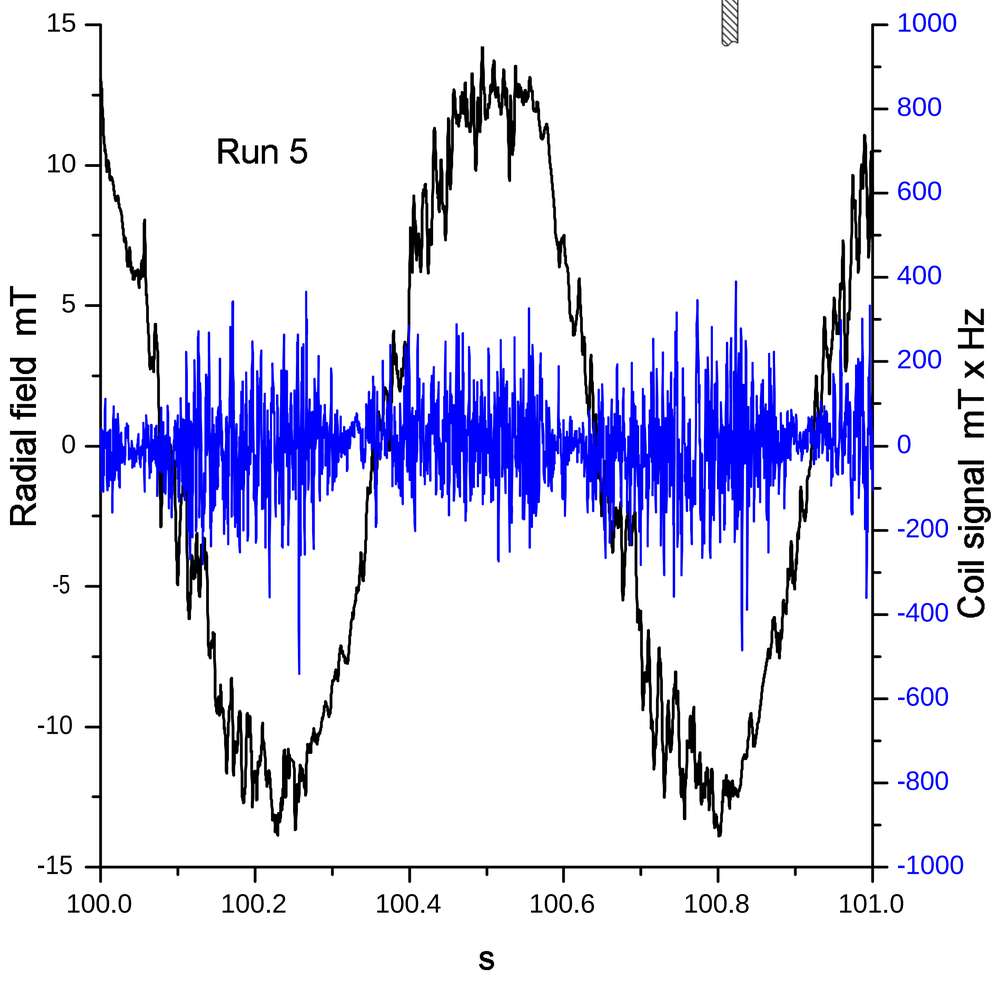

1.0
0.8
0.6
0.4
0.2
0.0
Bz mT
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
z m
2400 rpm
2300
2500
2100
2000
1900

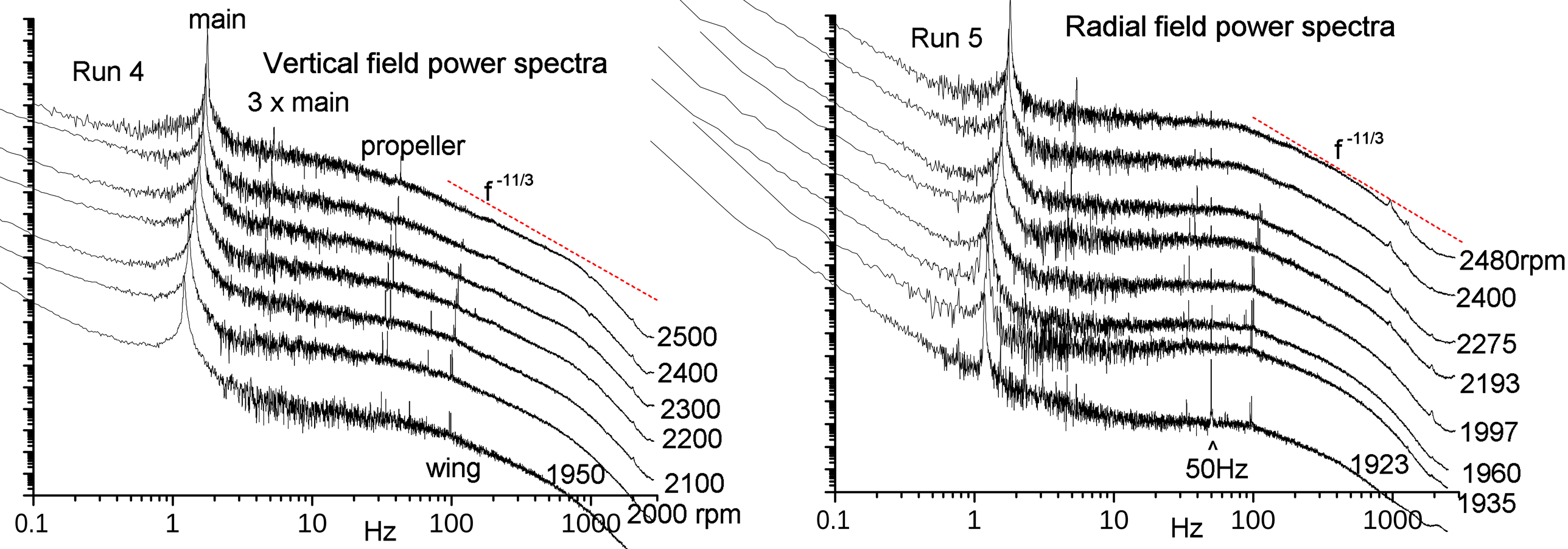

1900rpm
Bz
2500
Bφ
Br
1D theor.
phase deg.
300
250
200
150
100
50
0
-50
-100
-150
-200
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
z m


42mm
25mm
7mm
Inner Wall
7mm
5mm


Run 4
Vertical field mT
Coil signal mT x Hz
s
80
60
40
20
0
-20
-40
-60
-80
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
102.0
102.2
102.4
102.6
102.8
103.0


42mm
29mm
7mm
Inner Wall
7mm
5mm


Run 5
Radial field mT
Coil signal mT x Hz
s
15
10
5
0
-5
-10
-15
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
100.0
100.2
100.4
100.6
100.8
101.0


Run 4
Vertical field power spectra
main
3 x main
propeller
f -11/3
wing
2500
2400
2300
2200
2100
1950
2000 rpm
0.1
1
10
Hz
100
1000
Run 5
Radial field power spectra
f -11/3
2480rpm
2400
2275
2193
1997
1960
1935
1923
50Hz
0.1
1
10
Hz
100
1000

171458b
2090rpm

field horizont

signal horizont

Coil signal spectra

radial position

220

173

127

-105

80,6

-58

34

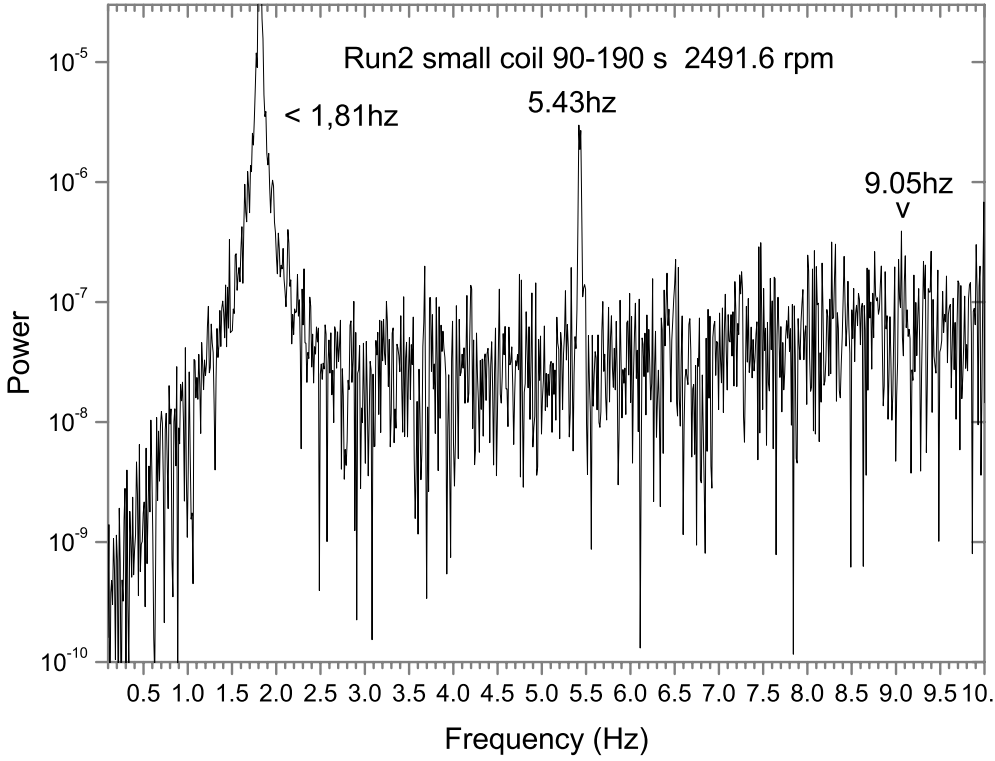
-12

1

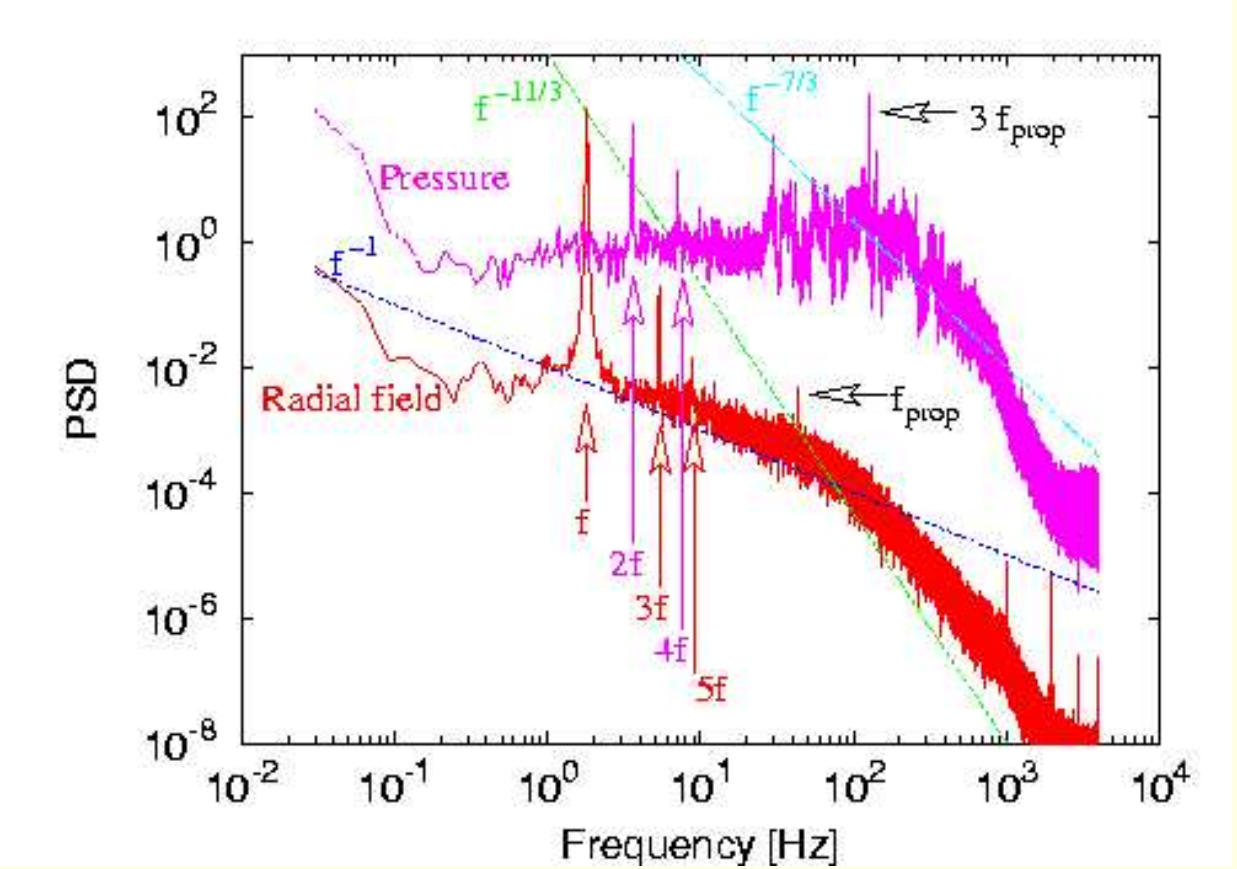
10

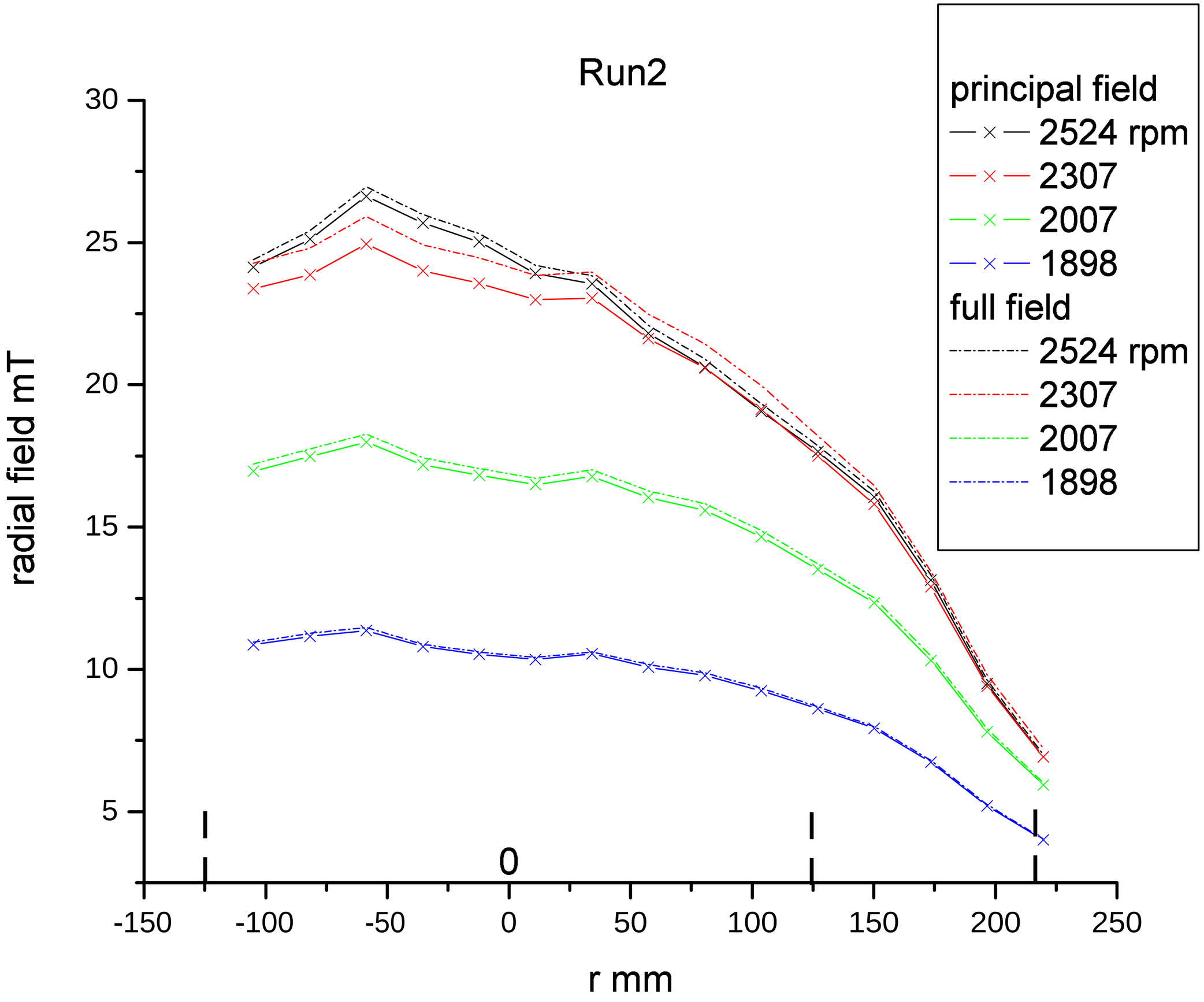
100

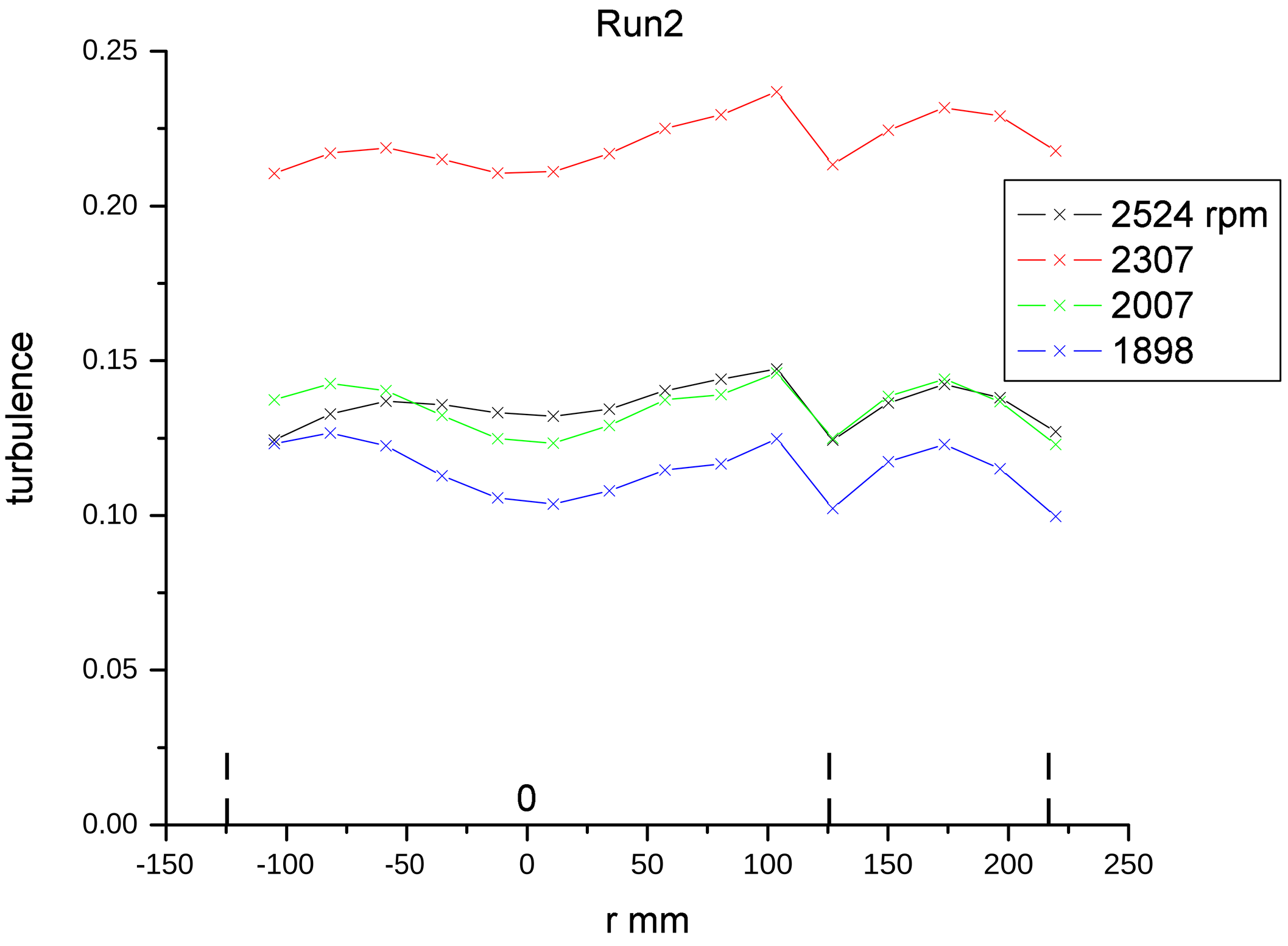
Hz


Run2 small coil 90-190 s 2491.6 rpm
< 1,81hz
5.43hz
9.05hz
Power
Frequency (Hz)

Run 1 - Spectra of radial field (tip) and pressure




Run2
principal field
2524 rpm
2307
2007
1898
full field
2524 rpm
2307
2007
1898
radial field mT
30
25
20
15
10
5
0
-150
-100
-50
0
50
100
150
200
250
r mm


Run2
0.25
0.20
0.15
0.10
0.05
0.00
turbulence
2524 rpm
2307
2007
1898
0
-150
-100
-50
0
50
100
150
200
250
r mm

β -- effect:

$$\sigma_T=\sigma/(1+(\mu_0\sigma v^T\lambda)^2/9)\approx$$

$$\approx\sigma/(1+(B^T/B_0)^2/9)\approx$$

$$\approx\sigma/(1+(B_r{}^T/B_r\times B_r/B_z)^2/3)\approx$$

$$\approx\sigma/(1+(0.15/3)^2/3)\approx 0.999\sigma$$

Energy balance at 2300 rpm:

Unperturbed kinetic energy:

in direct flow	5000 J/m
in rotation	1300 J/m
in back flow	2500 J/m
total	8800 J/m

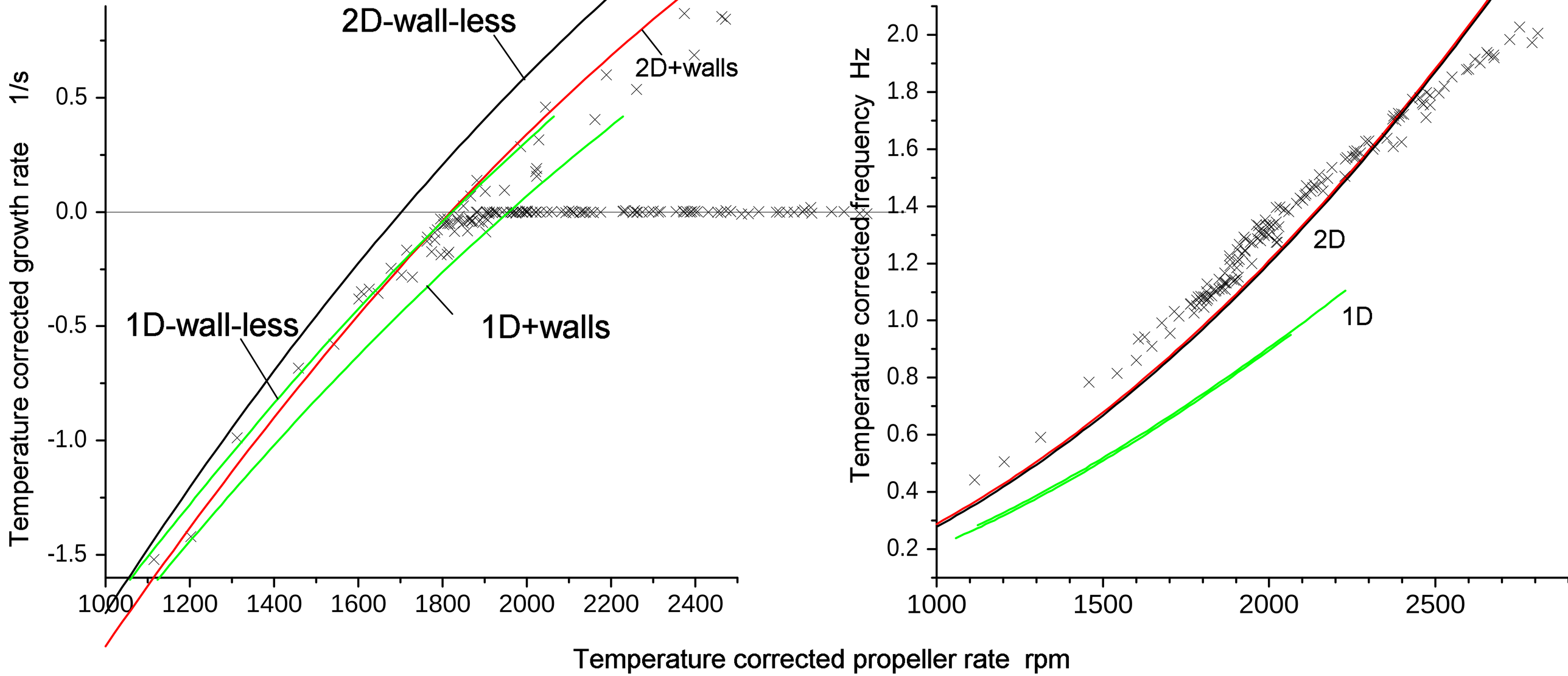
At measured level:

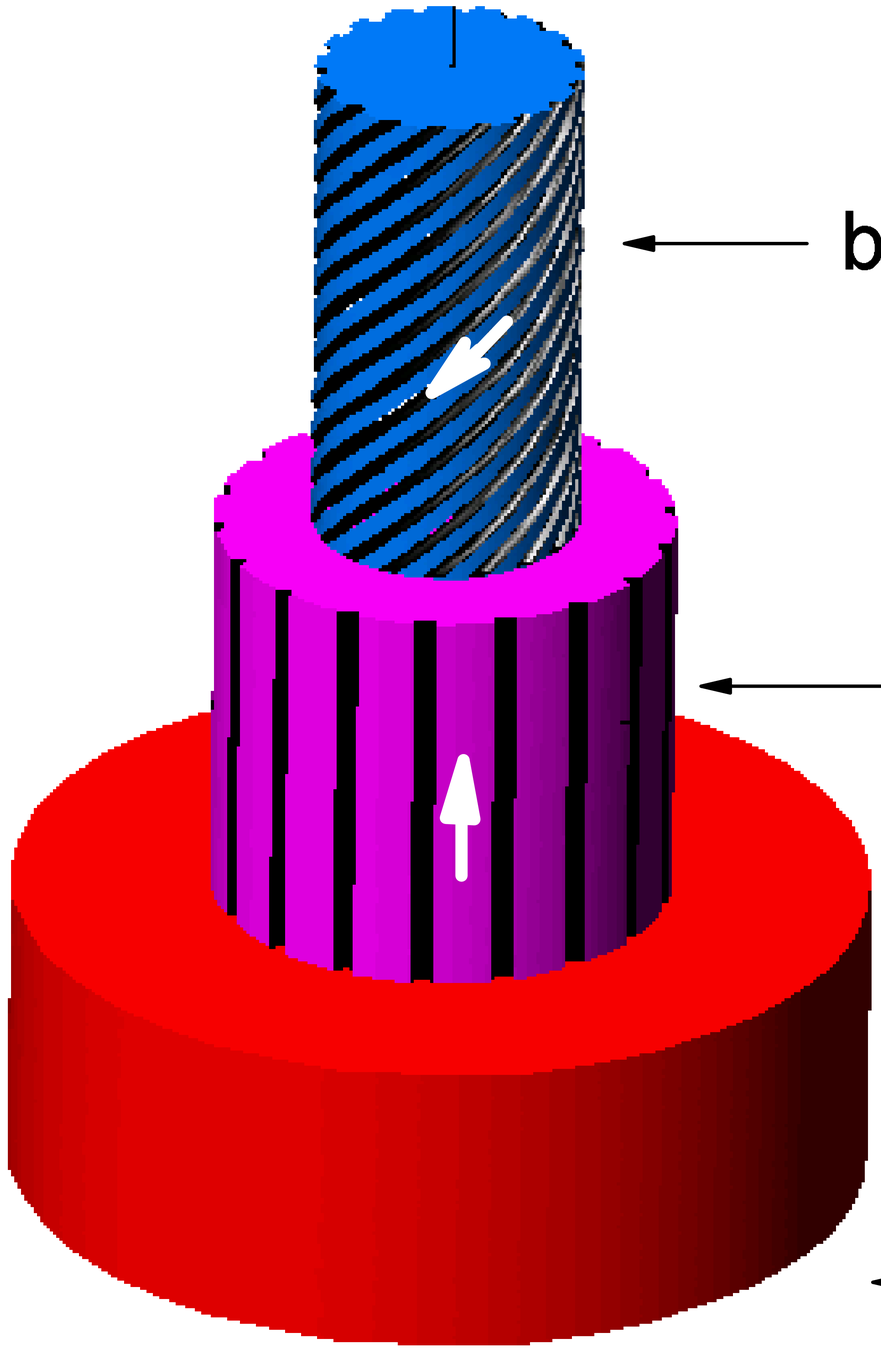
magnetic energy	175 J/m

Magnetic/kinetic 2%

$$\frac{\partial \vec{B}}{\partial t} = \nabla \times \vec{v} \times \vec{B} + \frac{1}{\mu_0 \sigma} \Delta \vec{B}$$

$$\vec{B}(\infty) \to 0$$


2D-wall-less
2D+walls
1D-wall-less
1D+walls
Temperature corrected growth rate 1/s
0.5
0.0
-0.5
-1.0
-1.5
1000
1200
1400
1600
1800
2000
2200
2400
Temperature corrected frequency Hz
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
2D
1D
1000
1500
2000
2500
Temperature corrected propeller rate rpm



$$B_r \pm iB_\varphi = b^{\pm}(r)\exp(i(kz+m\varphi-\omega t))$$

$$b^{\pm}(r) = a_1^{\pm} I_{m\pm1}(q_1 r)$$ *for solid velocity*

or power series for

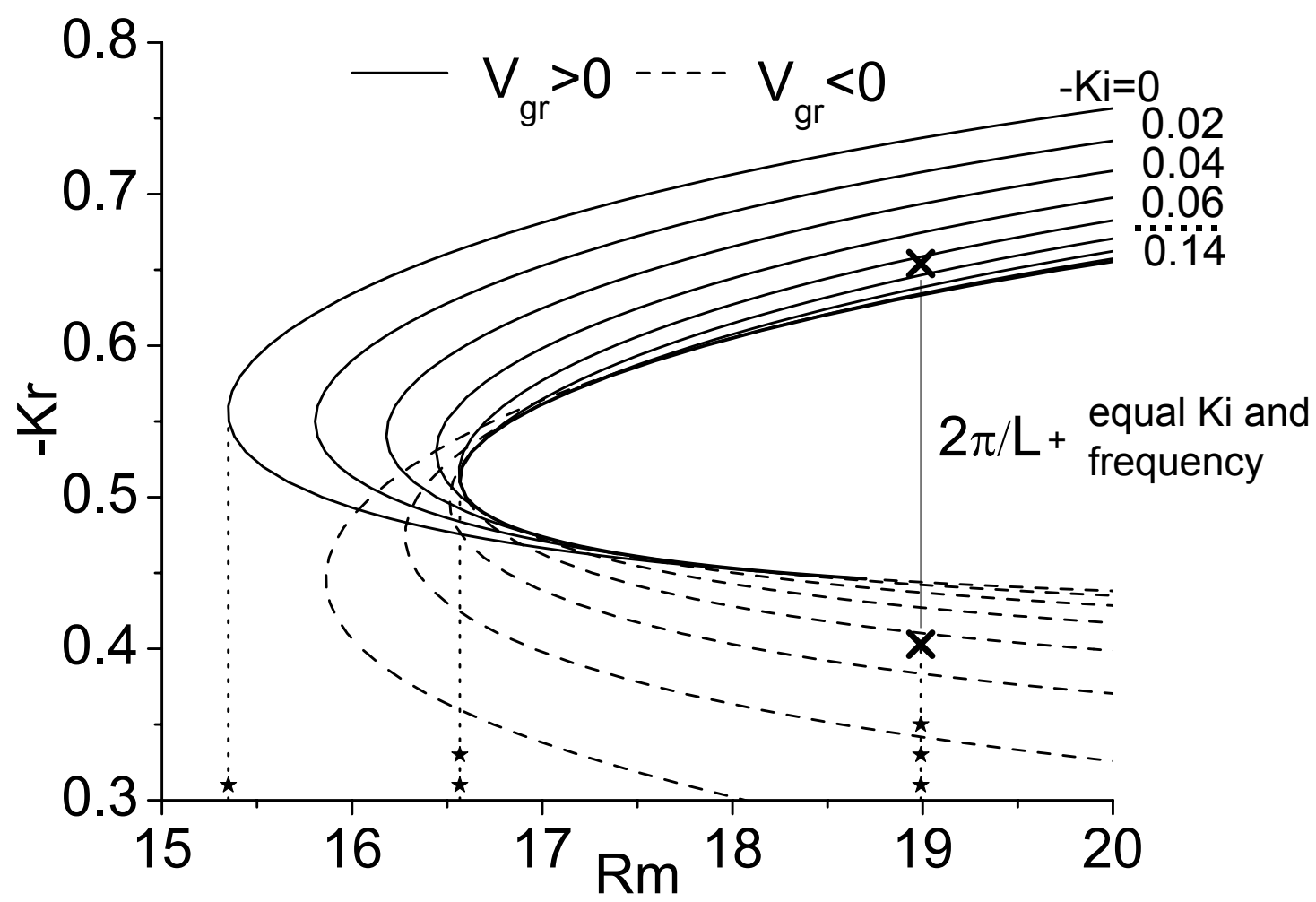
polinomial velocity profiles

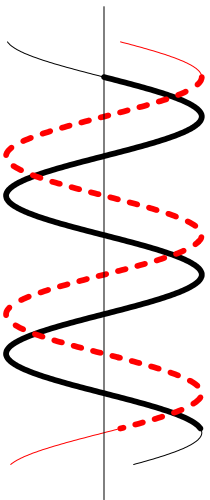
$$= a_2^{\pm} I_{m\pm1}(q_2 r) + c_2^{\pm} K_{m\pm1}(q_2 r)$$

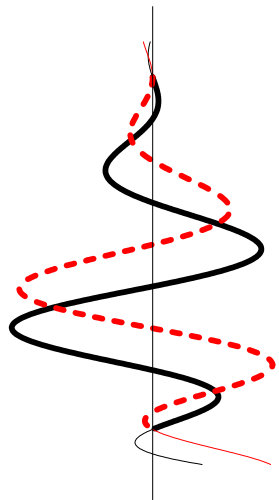
$$= a_3^{\pm} I_{m\pm1}(q_3 r) + c_3^{\pm} K_{m\pm1}(q_3 r)$$

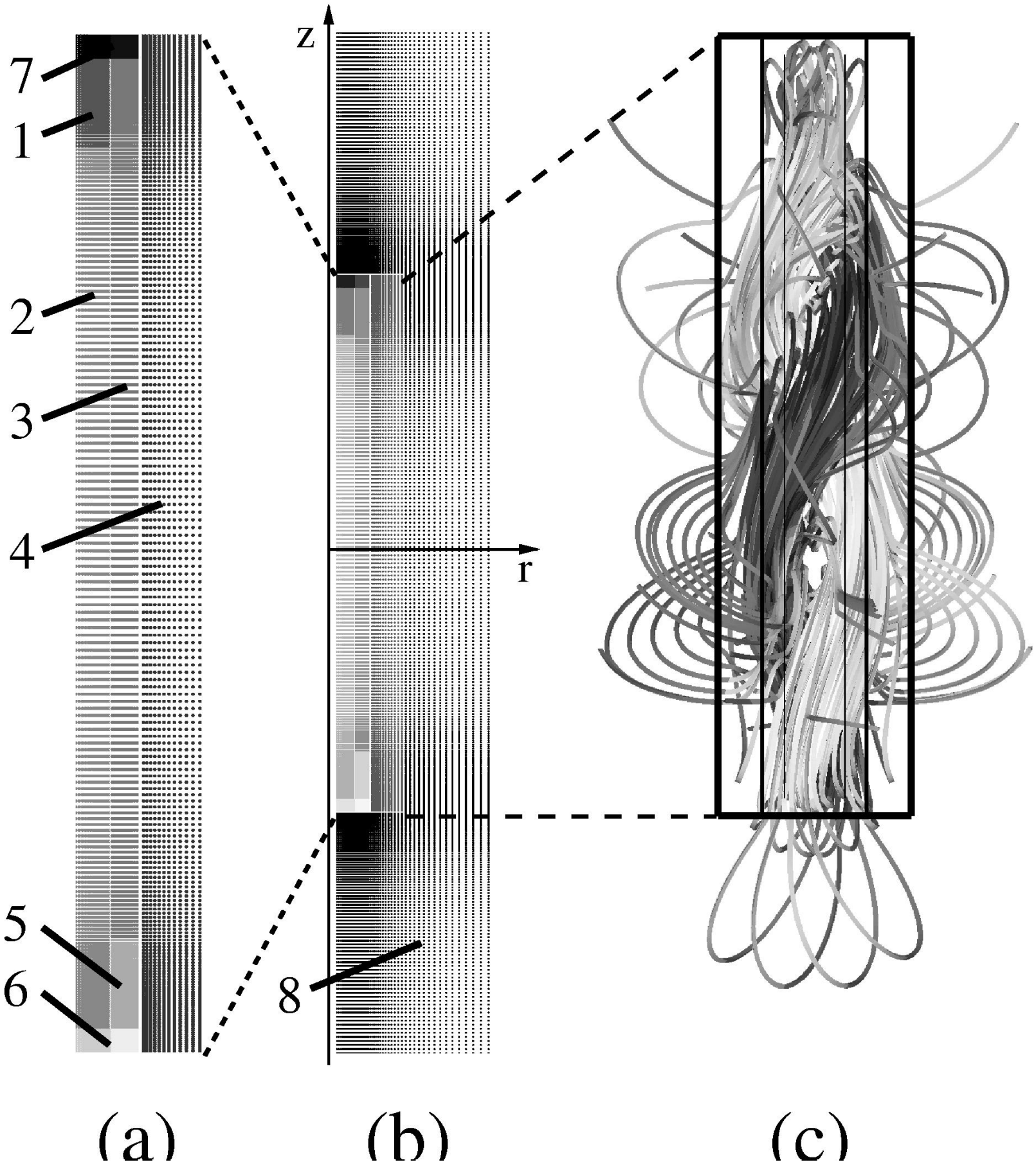
$$= c_4^{\pm} K_{m\pm1}(kr)$$ *in outer space*

$$q_n^2 = k^2 + i\mu_0\sigma\omega_n$$ ω_n*-frequency in co-moving frame*


0.8
0.7
0.6
0.5
0.4
0.3
-Kr
15
16
17
18
19
20
Rm
V_gr>0
V_gr<0
-Ki=0
0.02
0.04
0.06
0.14
2π/L+
equal Ki and
frequency






7
1
2
3
4
5
6
z
r
8
(a)
(b)
(c)

END