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V.K.Gusev [1], F.V.Chernyshev [1], **V.V.Dyachenko** [1], Yu.V.Petrov [1], N.V.Sakharov [1], O.N.Shcherbinin [1], V.L.Vdovin [2]

ICRH Experiments on the Spherical Tokamak Globus-M

[1] *A.F.Ioffe Physico-Technical InstituteSt.Petersburg, Russia*
[2] *I.V.Kurchatov Institute, Moscow, Russia*

e-mail contact: V.Dyachenko@mail.ioffe.ru

RF heating in tokamak plasmas

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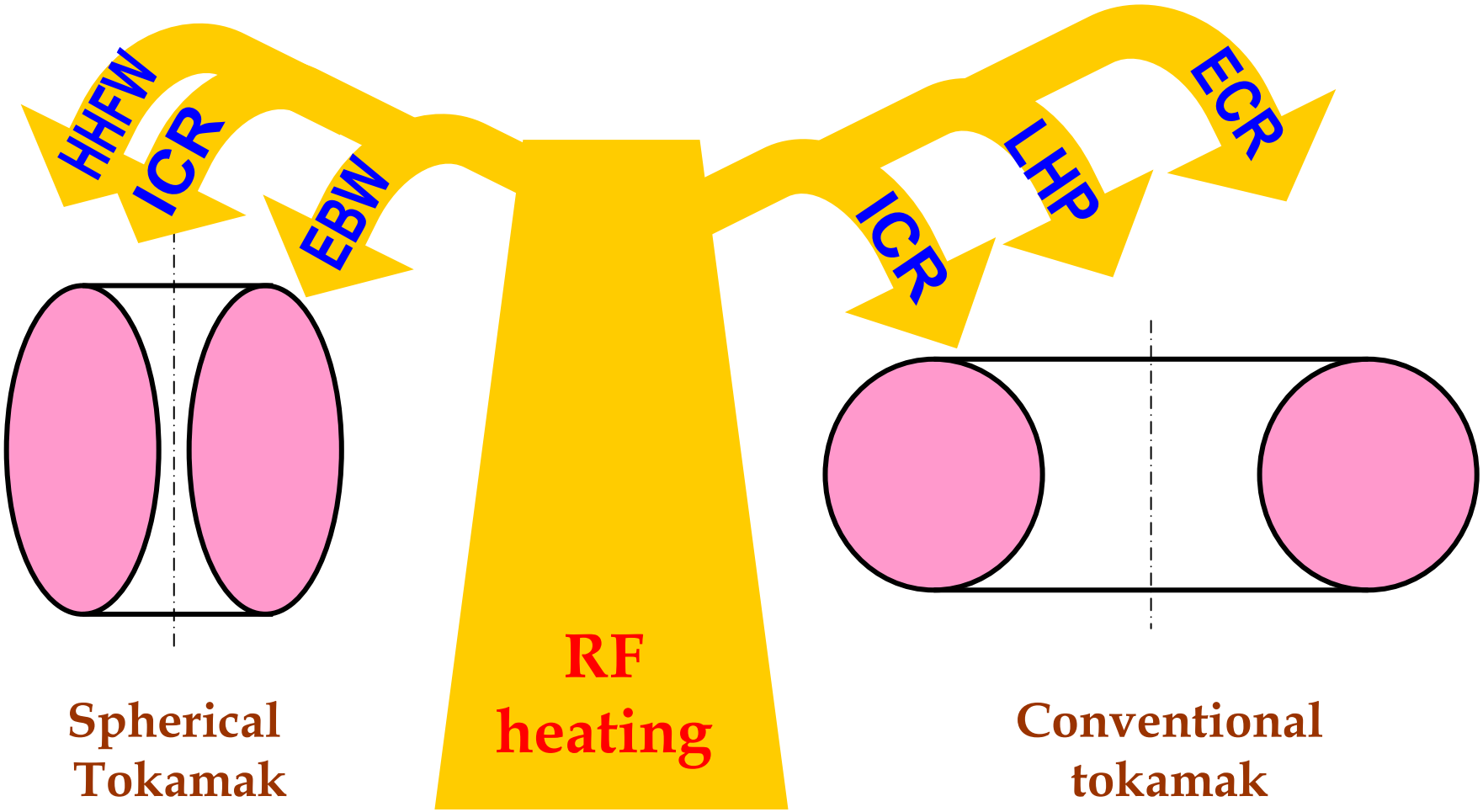

HHFW method by M.Ono, 1995

Difference in ICRF heating scenarios

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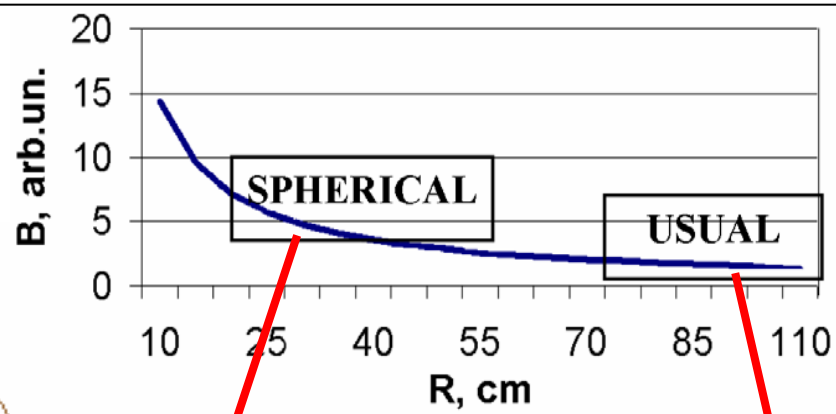

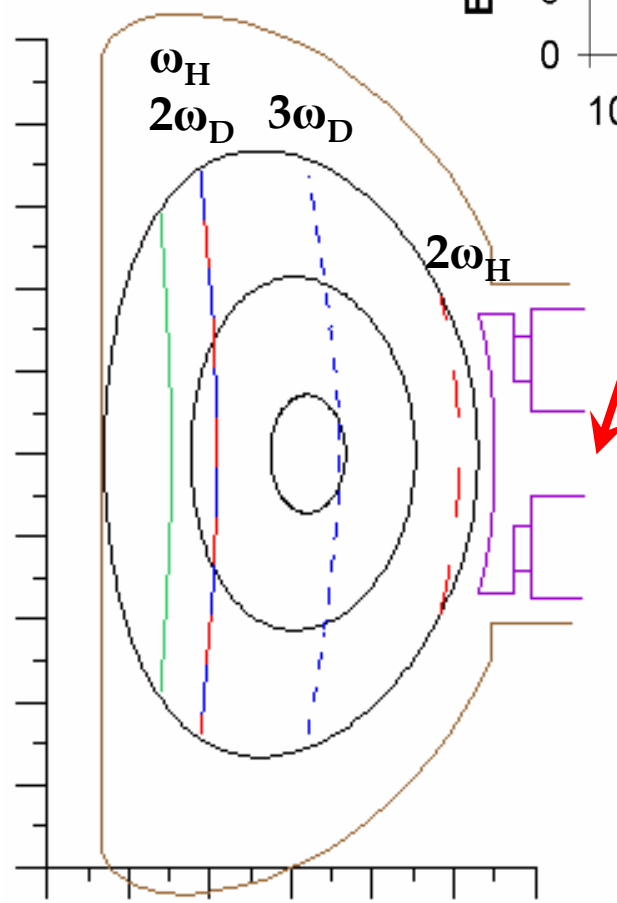

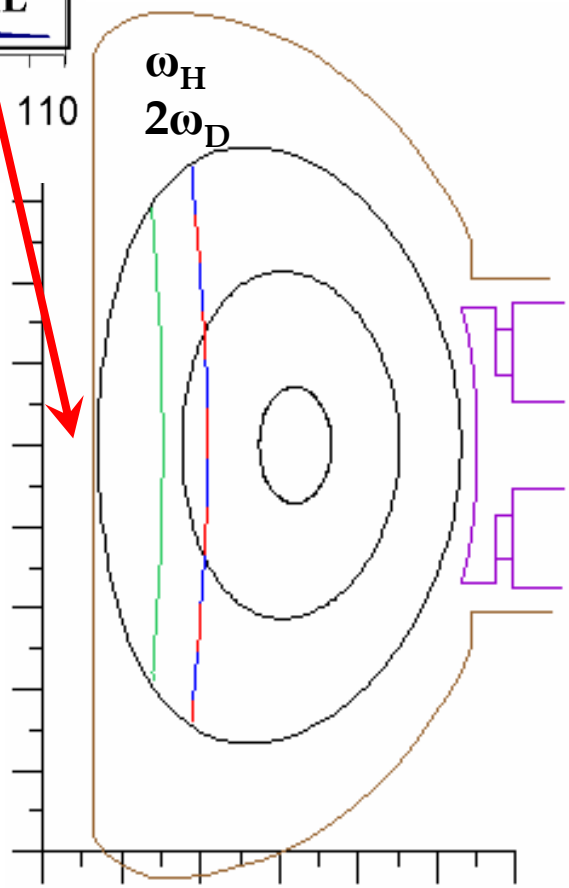

Several Resonances

One Resonance

Globus-M characteristics

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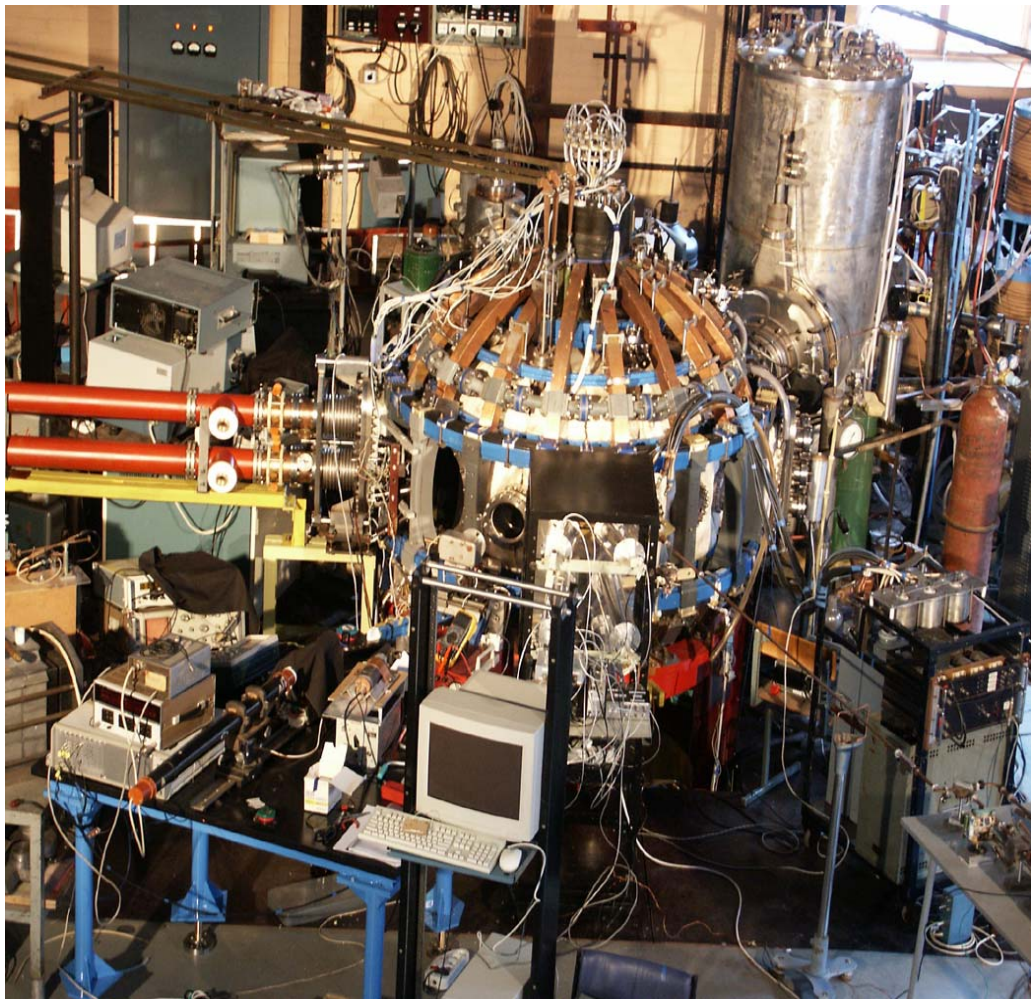
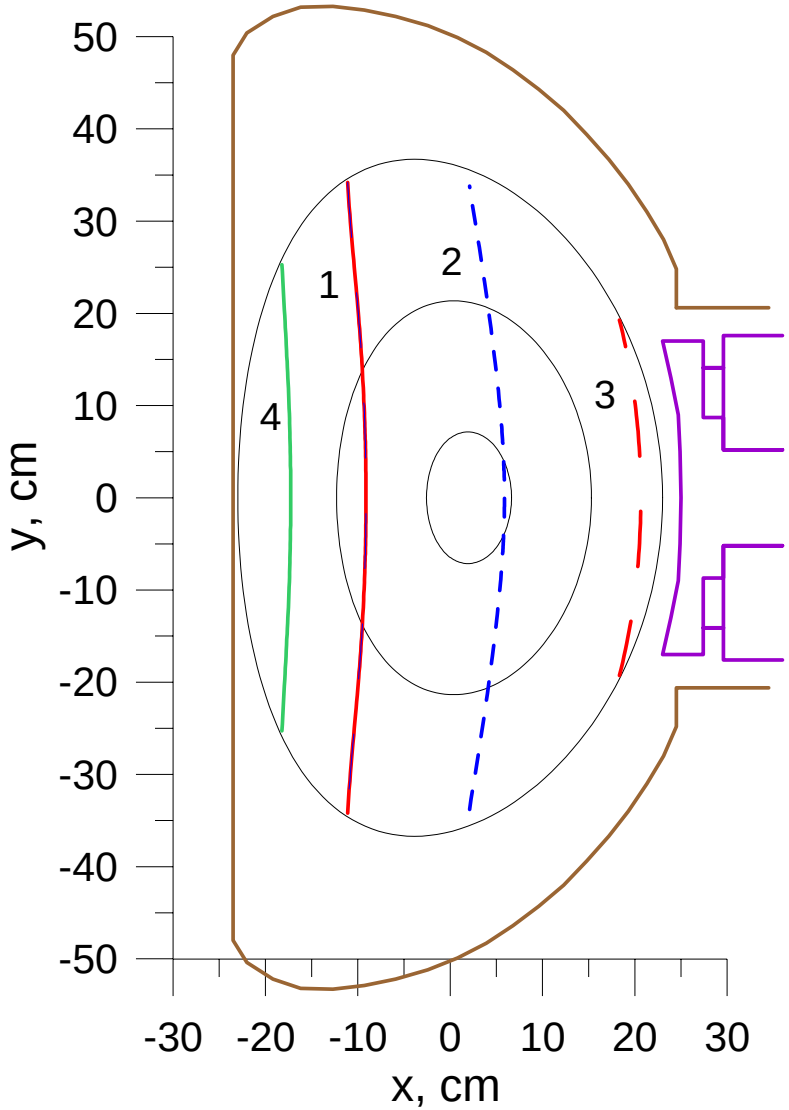


Parameter	Designed	Achieved
Toroidal magnetic field	0.62 T	0.55 T
Plasma current	0.5 MA	0.36 MA
Major radius	0.36 m	0.36 m
Minor radius	0.24 m	0.24 m
Aspect ratio	1.5	1.5
Vertical elongation	2.2	2.0
Triangularity	0.3	0.45
Average density	$1 \cdot 10^{20}$ m^{-3}	$0.7 \cdot 10^{20}$ m^{-3}
Pulse duration	0.2 s	0.085 s
Safety factor, edge	4.5	2
Toroidal beta	25%	~10% OH
ICRF power	1.0 MW	0.5 MW
Frequency	8 -30 MHz	8 –30 MHZ
Duration	30 mc	30 mc
NBI power	1.0 MW	0.7 Mw
Energy	30 keV	30 keV
Duration	30 mc	30 mc

The Globus-M chamber cross-section



Black ovals – magnetic flux surfaces ψ=0.2, 0.6, 1.0, ellipticity – 1.6, triangularity – 4 cm, Ip = 250 kA. Cyclotron surfaces for f = 9 MHz and B_0 = 0.4 T:

1 – deuterium second harmonic and hydrogen fundamental resonance

2 – third harmonic for deuterium

3 – second harmonic for hydrogen and fourth harmonic for deuterium

4 – ion-ion hybrid resonance for 50%H+50%D.

The fundamental resonance for deuterium is just outside of the magnetic surface ψ = 1.0

RF energy absorbtion profiles for f=9 MHz

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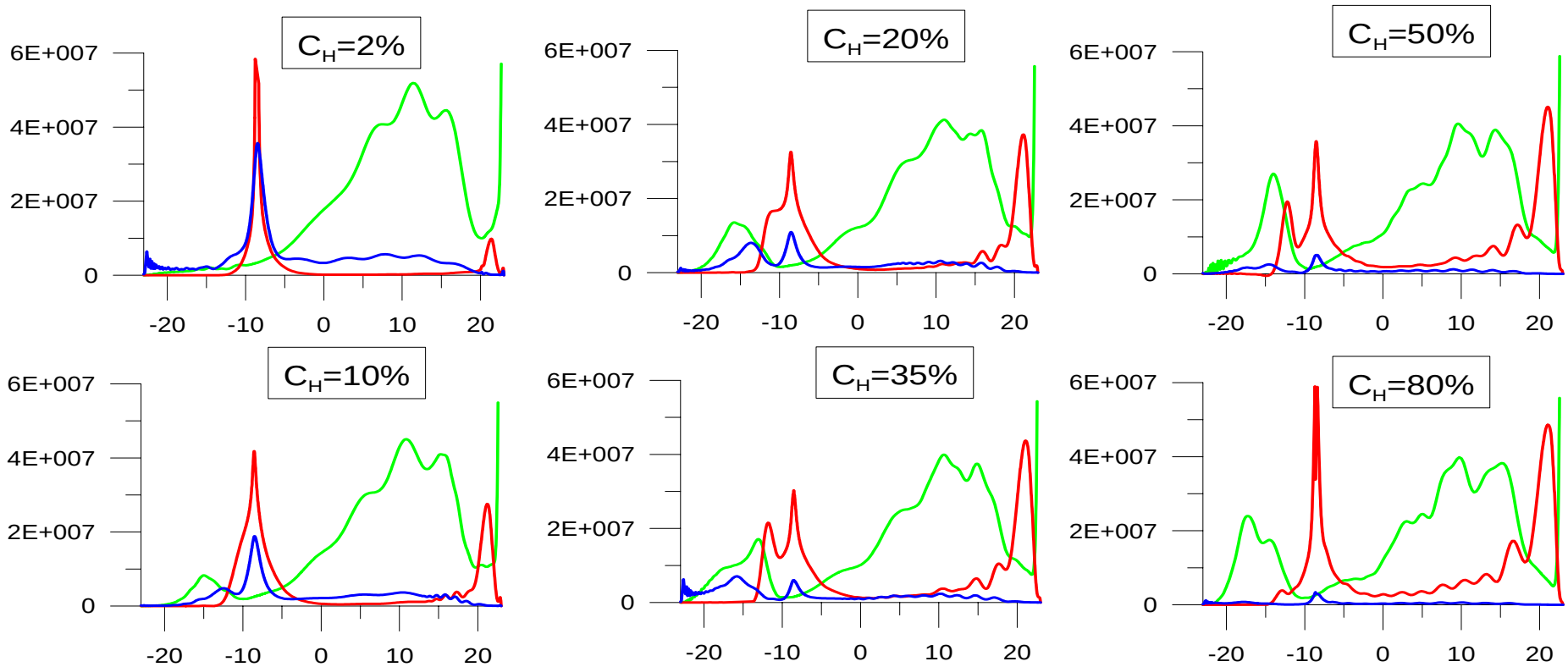
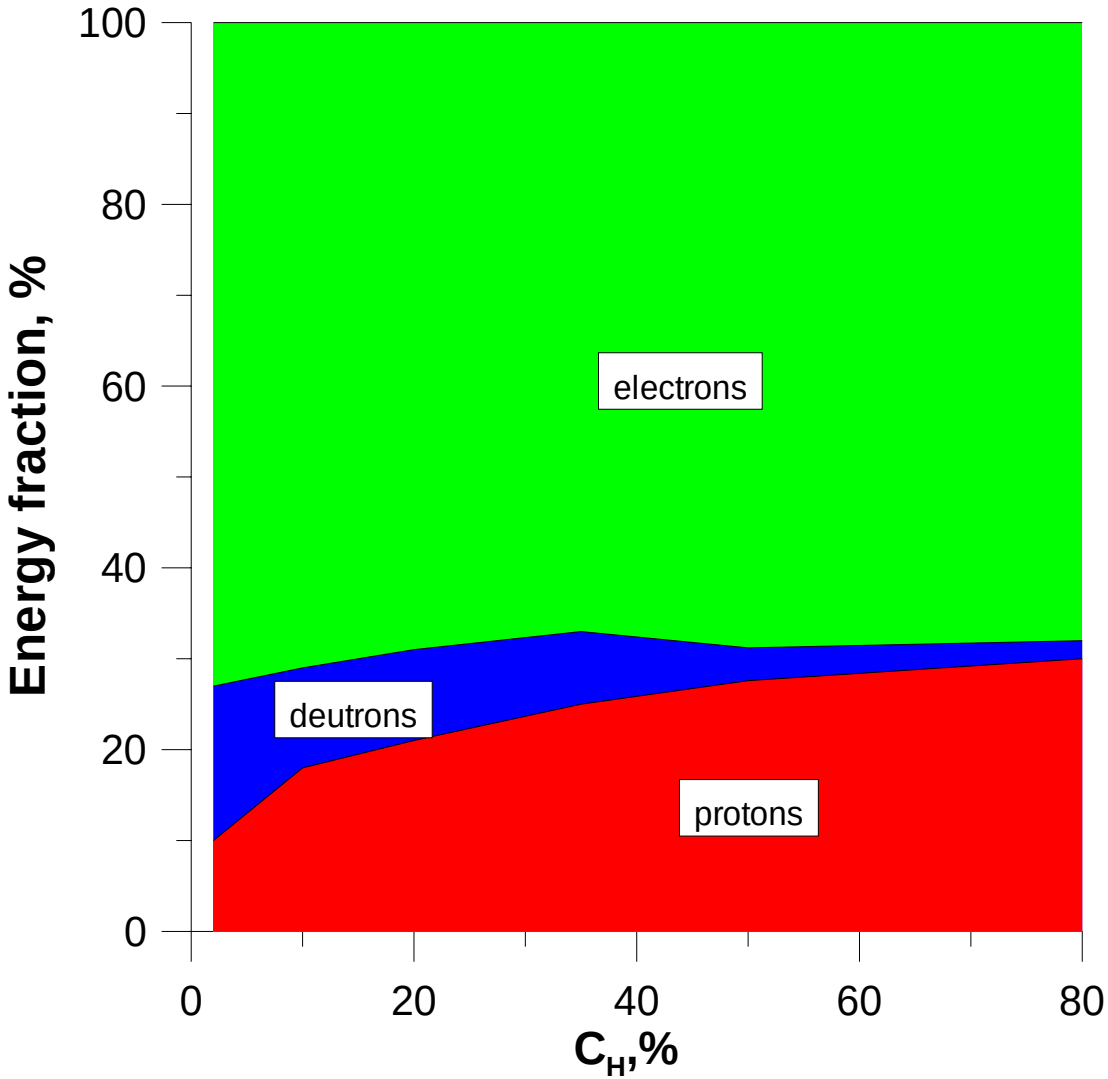
calculated for equatorial Globus-M parameters:
B0 = 0.4 T, Ip= 250 kA, ne0= $5 \cdot 10^{13} cm^{-3}$.



absorption by electrons (TTMP and Landau damping)
absoption by protons and by deuterons (cyclotron absorption and Bernstein wave absorption)

RF energy absorbtion distribution
between various plasma particle populations integrated over plasma diameter

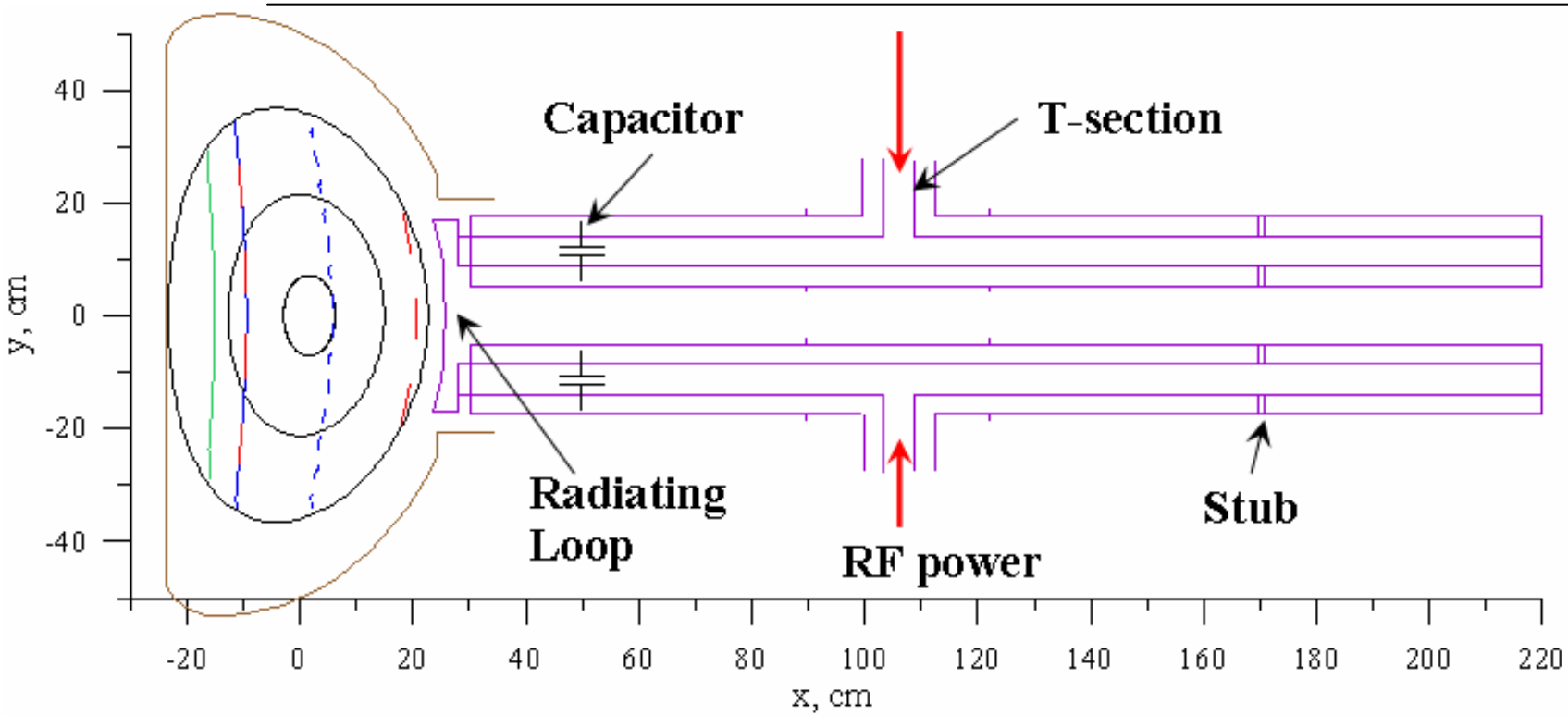


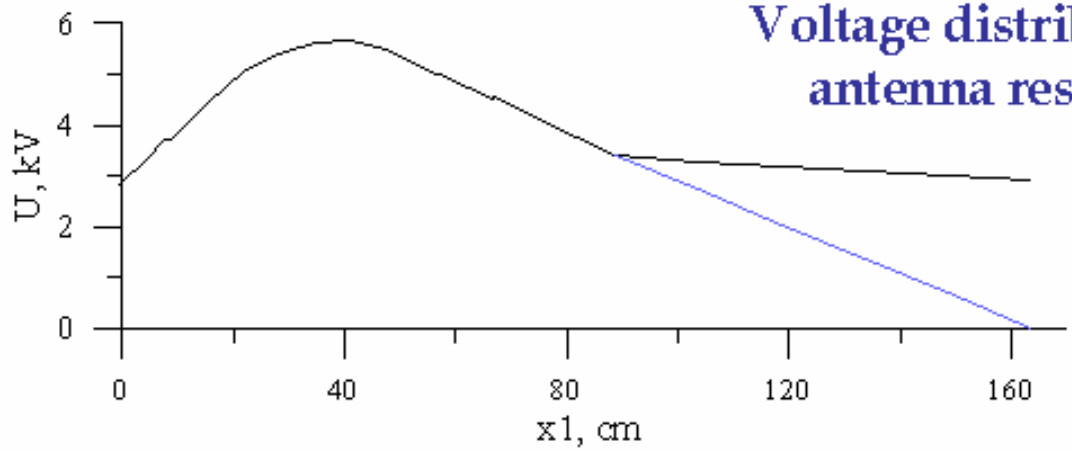
The calculation was peformed in 1D cylindrical model assuming plasma parameters characteristic for equatorial plane of Globus-M tokamak.

$B_0 = 0.4$ T, Ip= 250 kA,
$n_{e0} = 5 \cdot 10^{13} cm^{-3}$

The couplind resistance was obtained to be practically independent of hydrogen content

Sketch of antenna resonator





Voltage distribution in antenna resonator

RF heated Globus-M discharges

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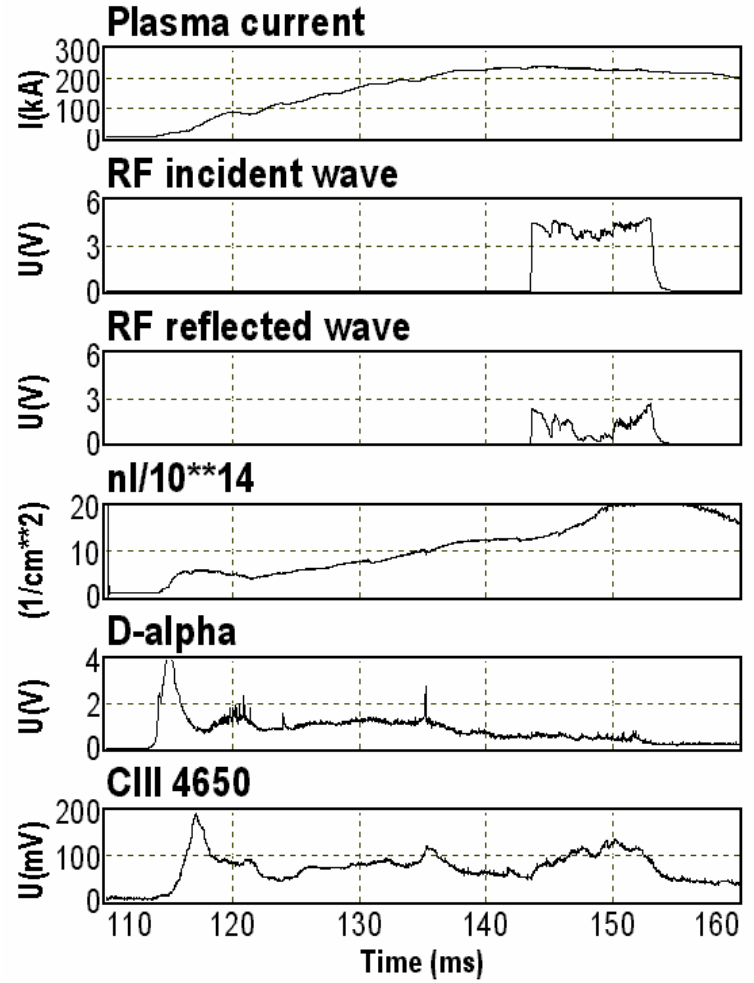
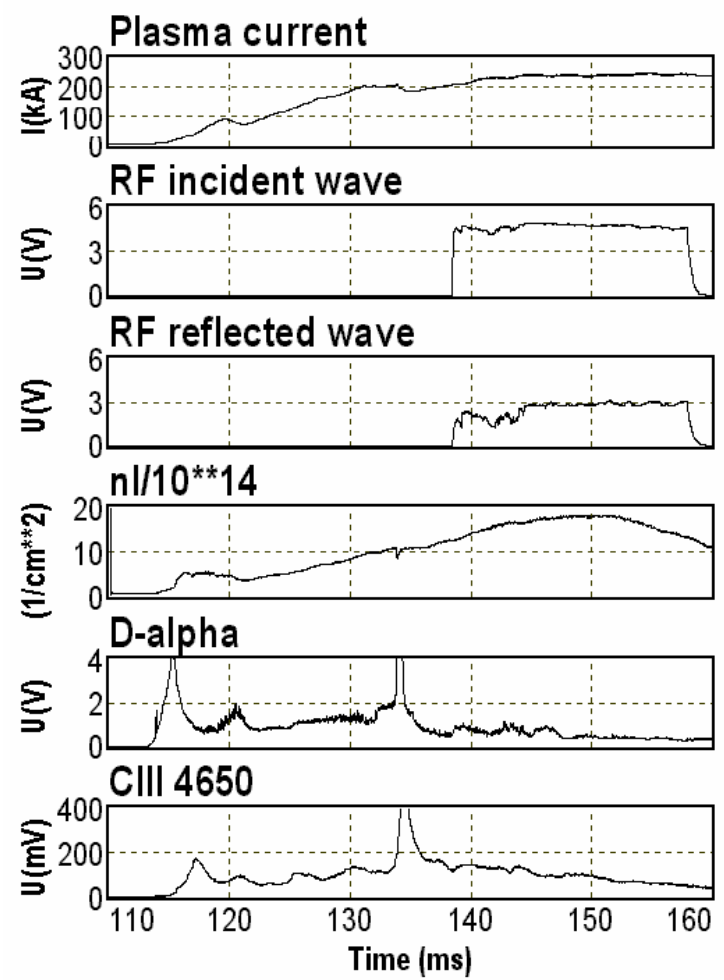
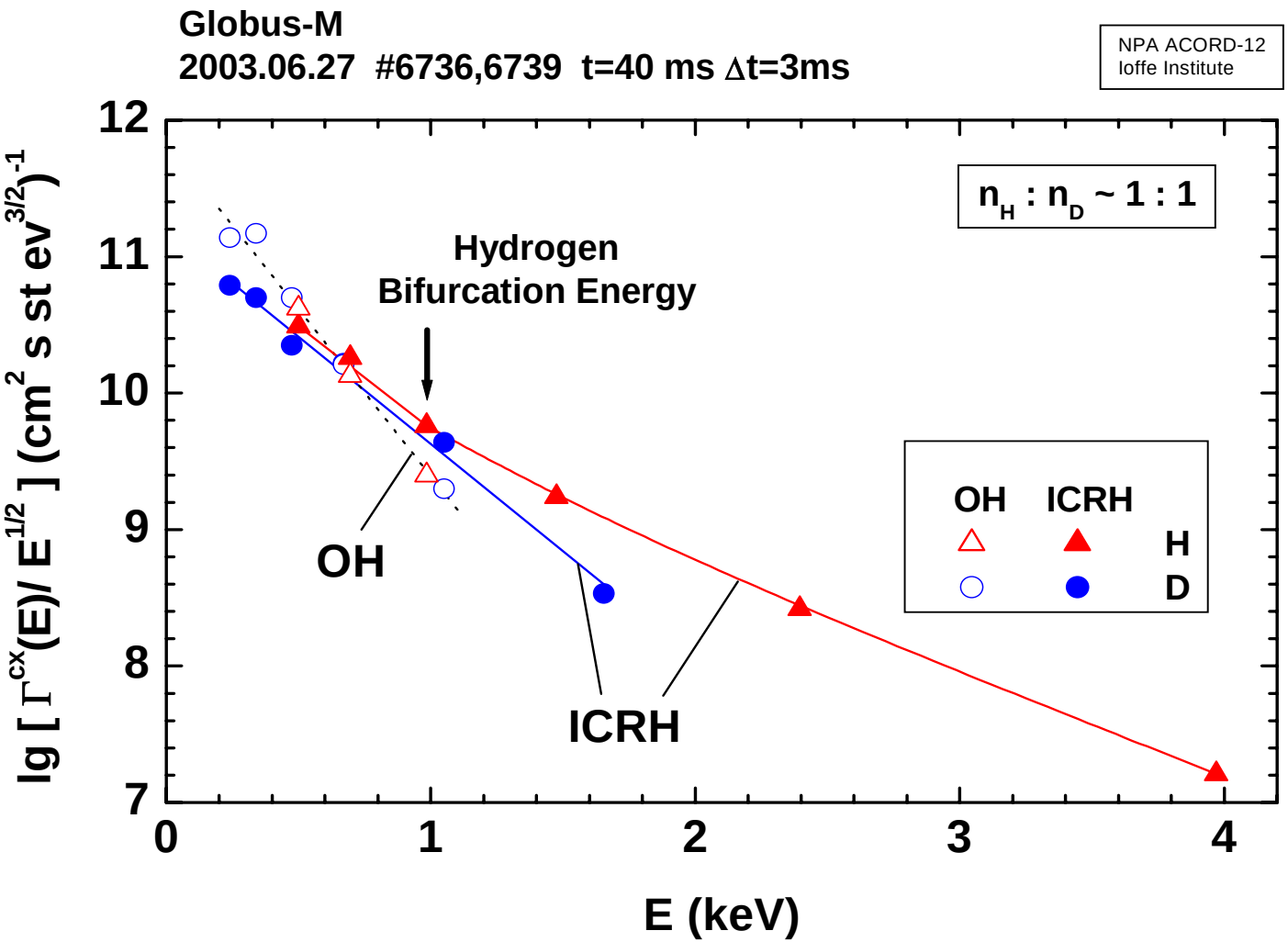


Conditioning…



After Conditioning

Energy Spectra of Ions with/without RF pulse



I_P=240 kA

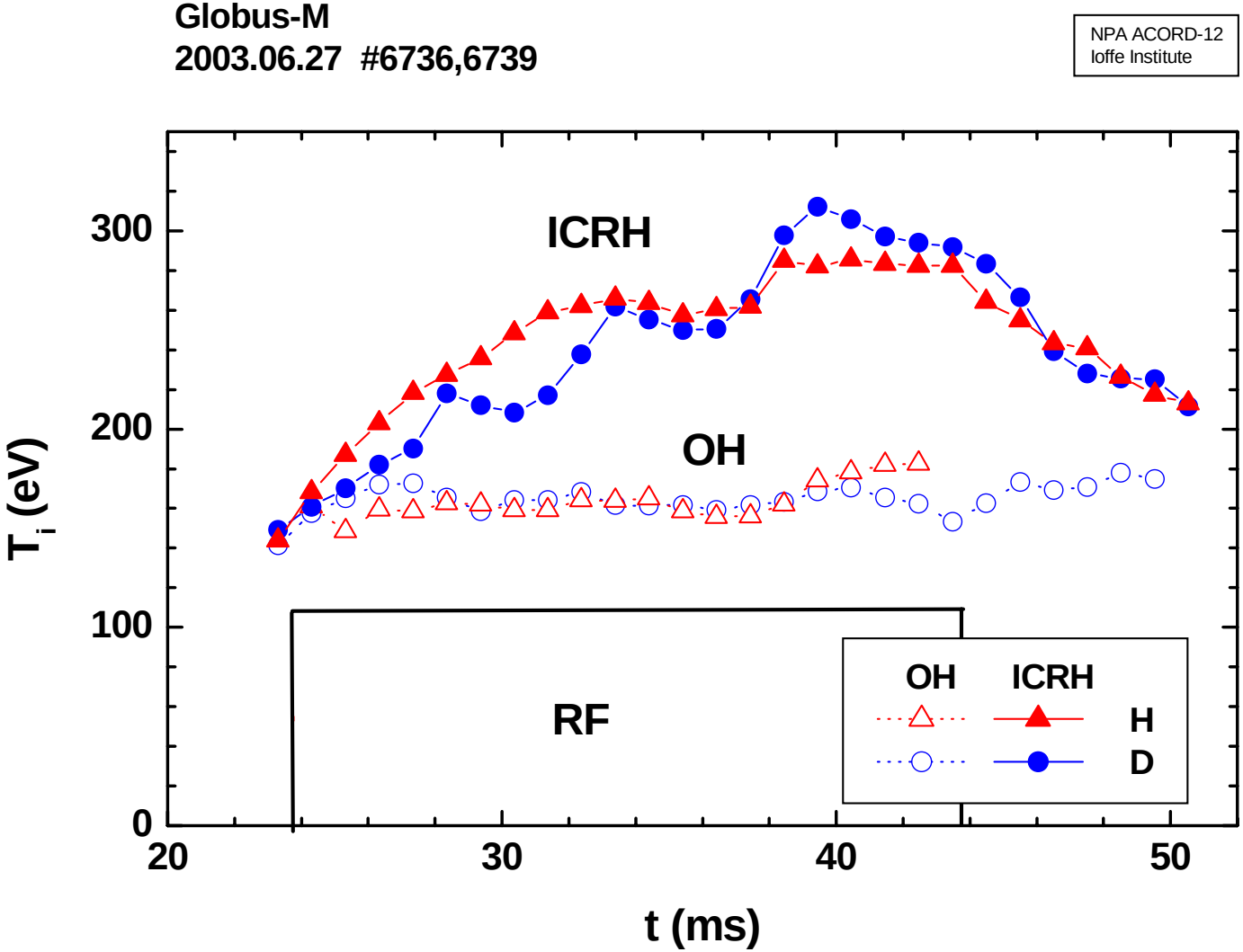
$n_e(0)=4.5.10^{10}$ m^{-3}

P_{inp}=150 kW

f=9.2 MHz

n_H/n_D=1

Evolution of Ion Temperature with/without RF pulse



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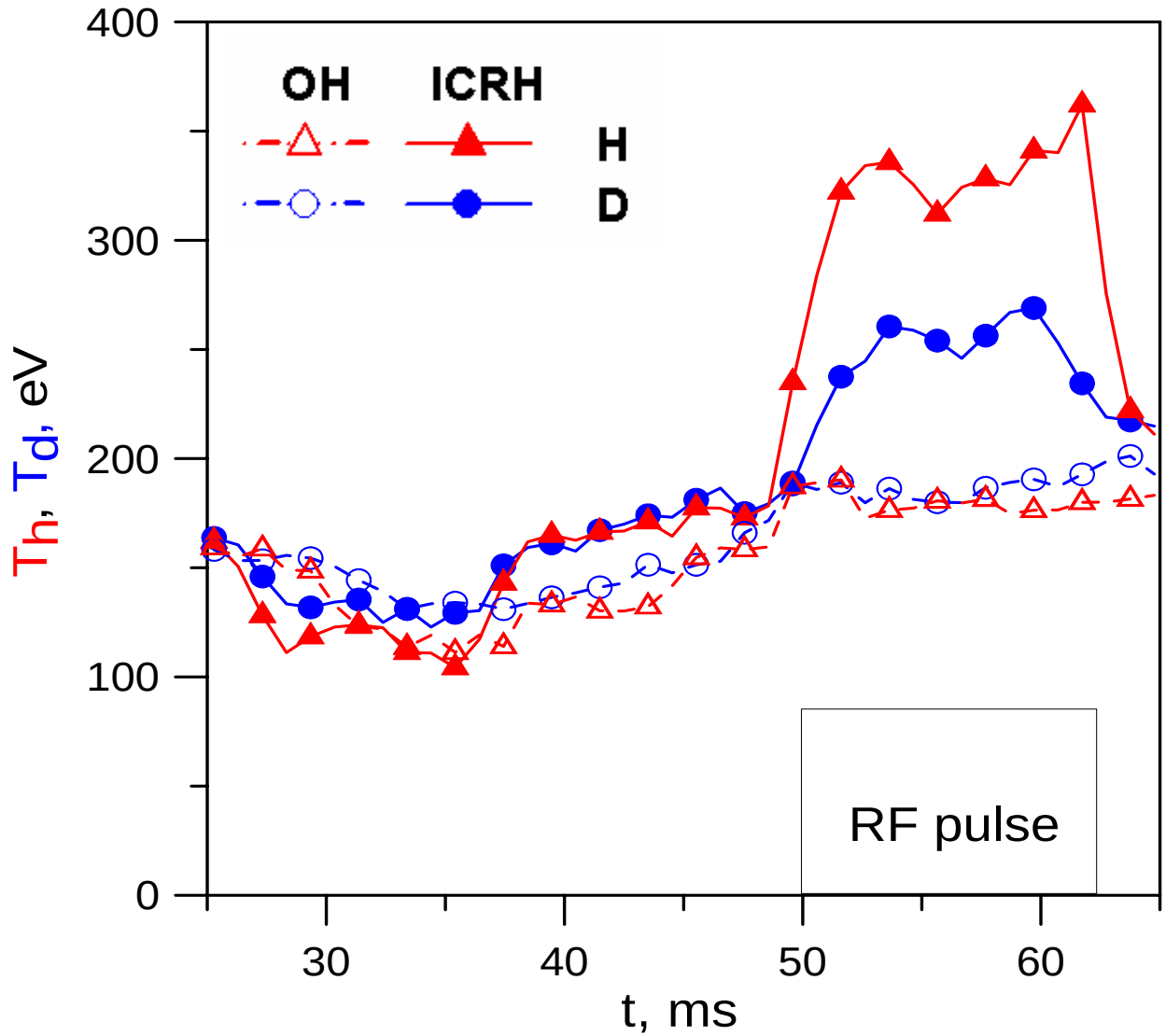

Shot 9287,9293

(June 2004)

B_0=0.4 T

I_p= 195 kA

n_H/n_D=0.25

f= 8.82 MHz

P_{inp}= 150 kW

Magnetic Field Distribution
In equatorial plane of the Globus-M chamber

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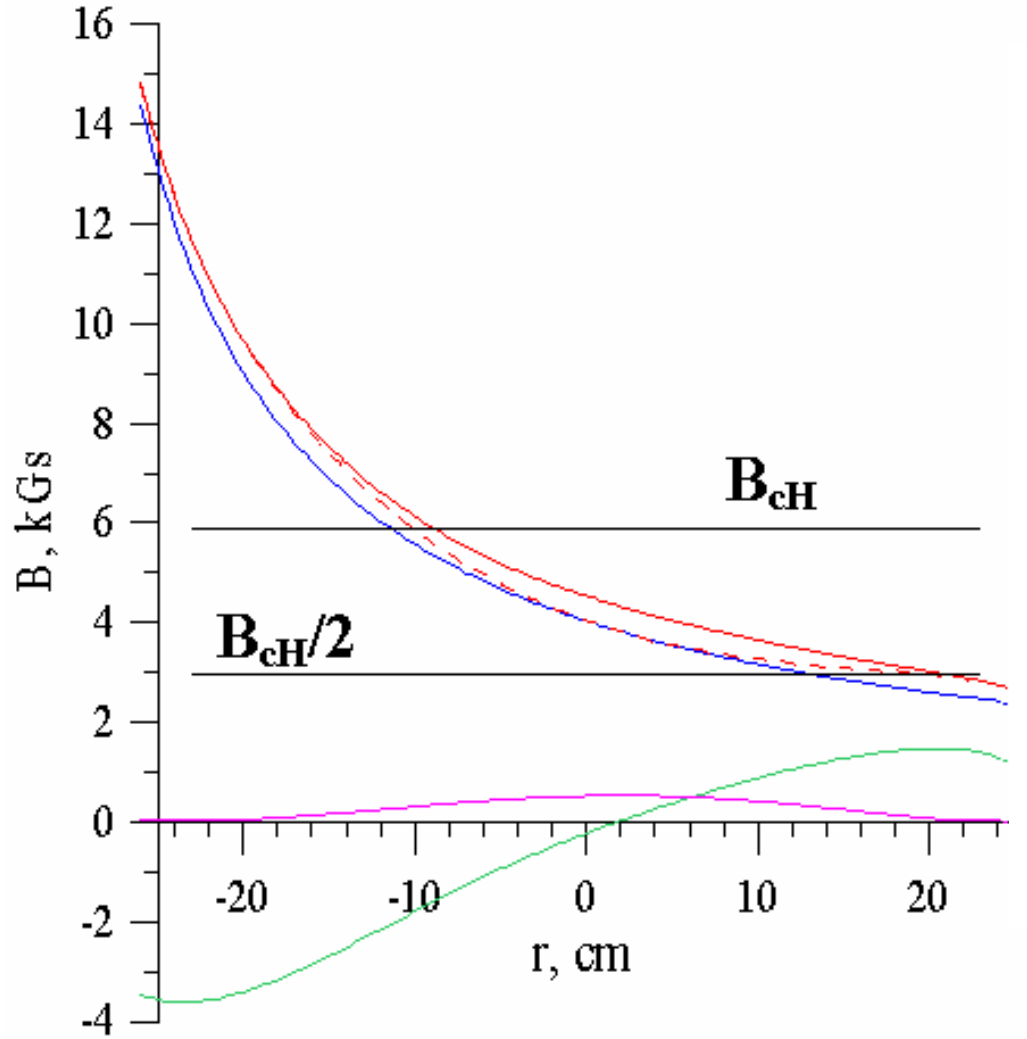

$R_0 = 36$ cm, $a_0 = 23$ cm

$B_0 = 0.4$ T, $I_p = 250$ kA, f=9 MHz

blue line – toroidal vacuum field

green line – poloidal field

violet line – paramagnetic field

red line – full magnetic field

dashed red line – full magnetic field without paramagnetic component

Conclusions

- The ICRF heating experiments were started on the Globus-M tokamak with low aspect ratio where conditions for several cyclotron harmonics were fulfilled simultaneously.
- The experiments were performed with hydrogen-deuterium plasma with various ratios of ion components (with hydrogen fraction from 20% to 50%).
- In some condition the ion temperature was almost doubled. But role of different absorption mechanisms and their dependence on discharge parameters is not clear yet.

Globus-M RF antenna
Outside arrangement

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