Overview of experience with RF on TEXTOR

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♦ Prehistory

- **ERASMUS antenna (slide 02)**

♦ History

- **"Old" TEXTOR antennas: Double hlf-turn tilted screen (slide 03-04)**
- **"New" TEXTOR antennas: Two LFS antenna pairs, one with feeder cover, the other without (slide 05-11)**
- **Unshielded electrostatic antenna (slide 12)**
- **One shielded, one unshielded (both with feeder cover) (slide 13)**
- **Two unshielded antennas (both with feeder cover)**

+ automatic tuning (slide 14-15)

- **One pair with 3-tubes strap (Low electric field) (slide 16-20)**

♦ Future

- **Resonant half loop (slide 21)**

♦ Technology and applications

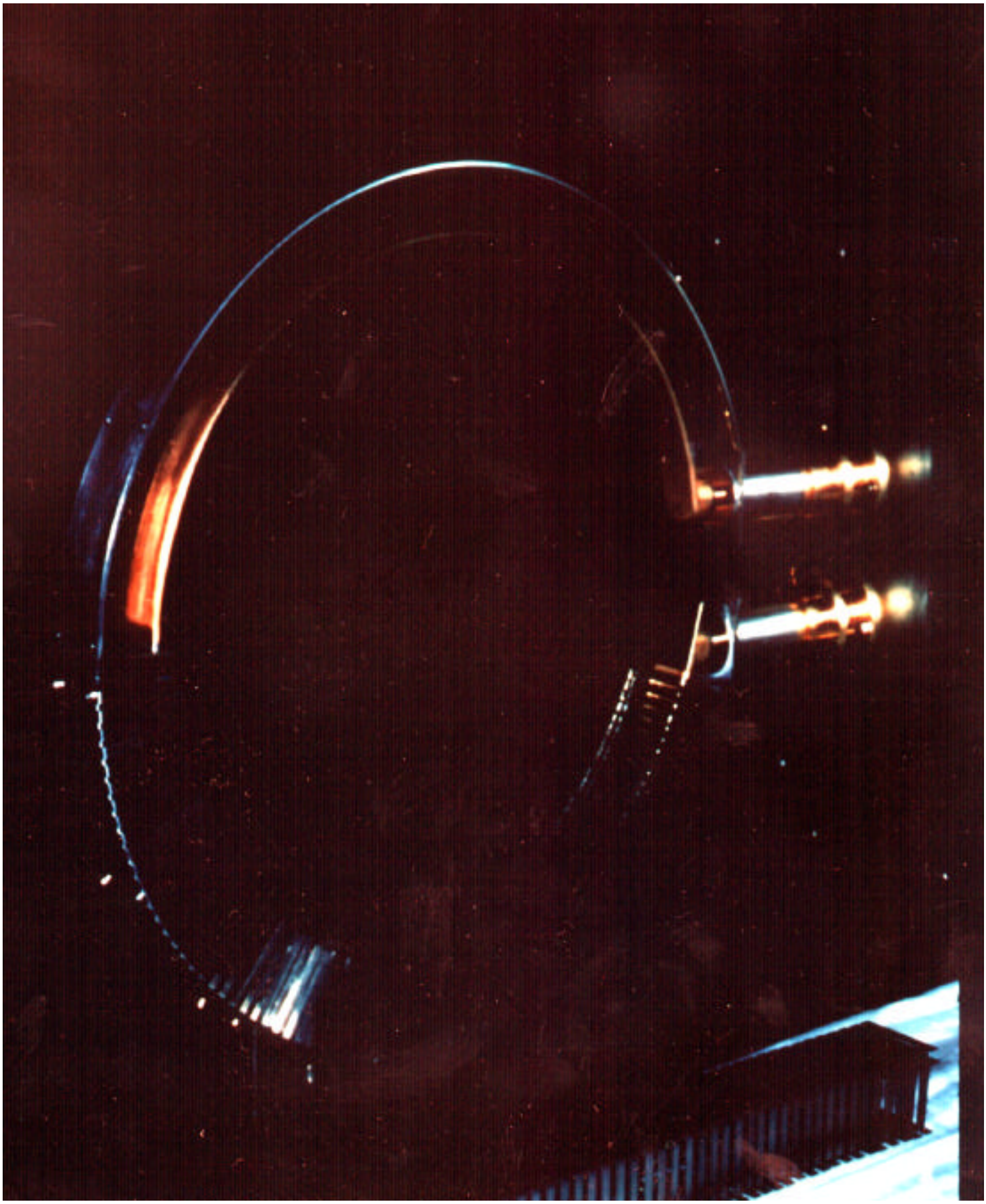
- Harmonic filter, Energy feedback control (slide 22)
- No problem for 15 years with ceramics near highest voltage point at antenna feeding area (slide 23-24)
- Plasma production for • Wall coating and conditioning • current start-up assistance (slide 25-26)

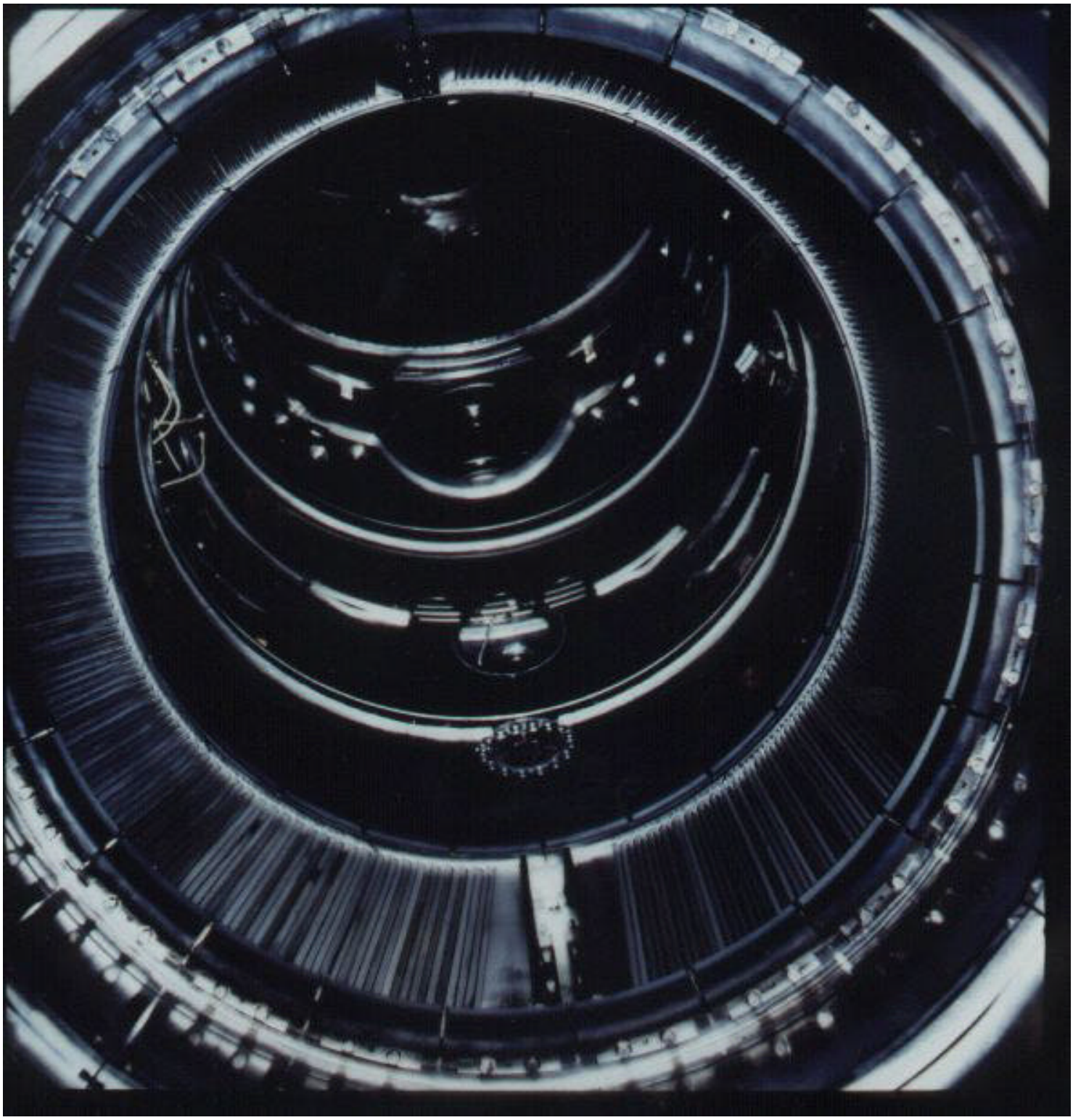
♦ Performance

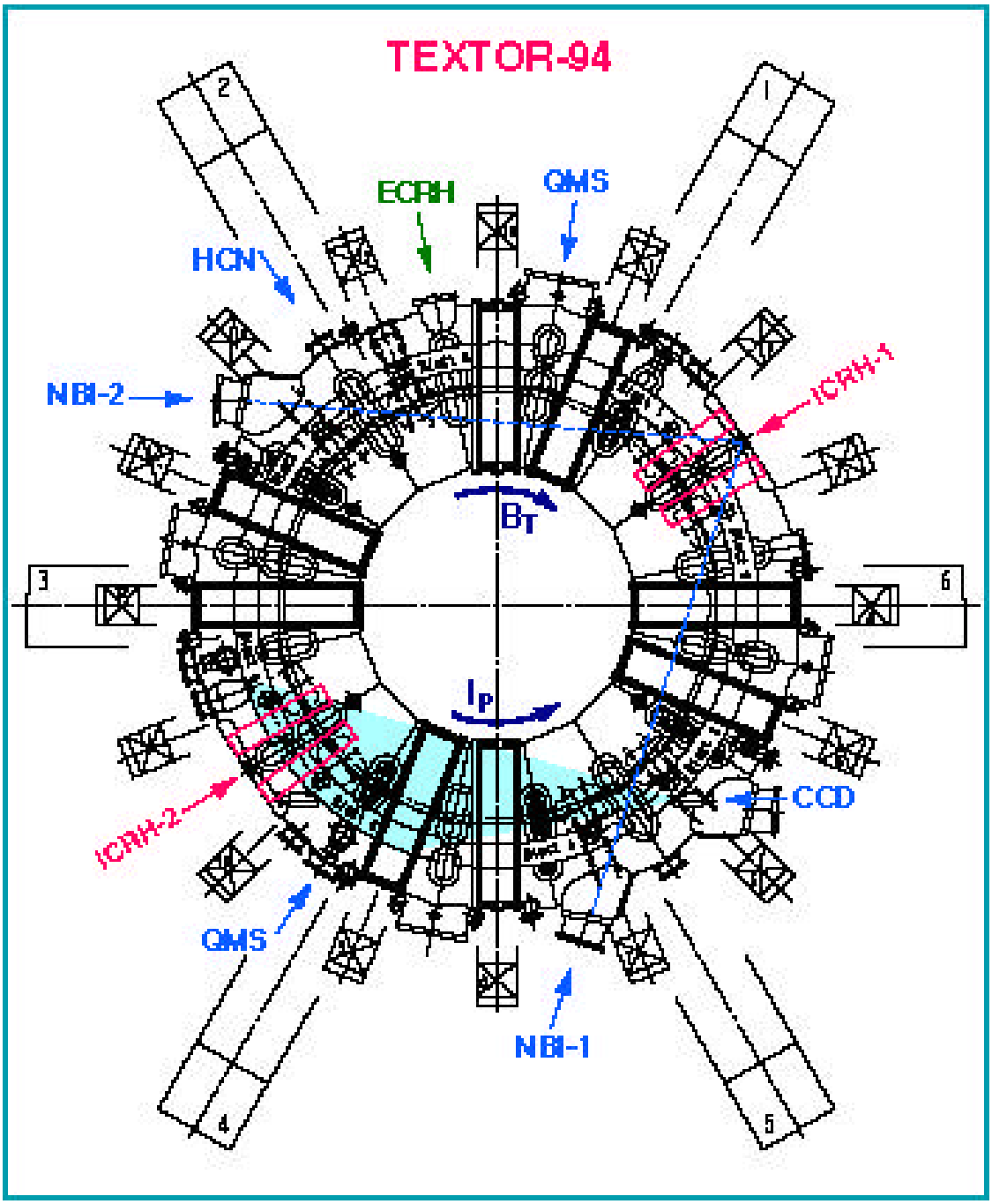
- Highest power density 7-8 MW/m^2 , long pulse at full power (slide 27)
- Reproducible full-power operation with both standard and 3-tubes straps antenna pairs (slide 28-29)

SOME CONCLUSIONS

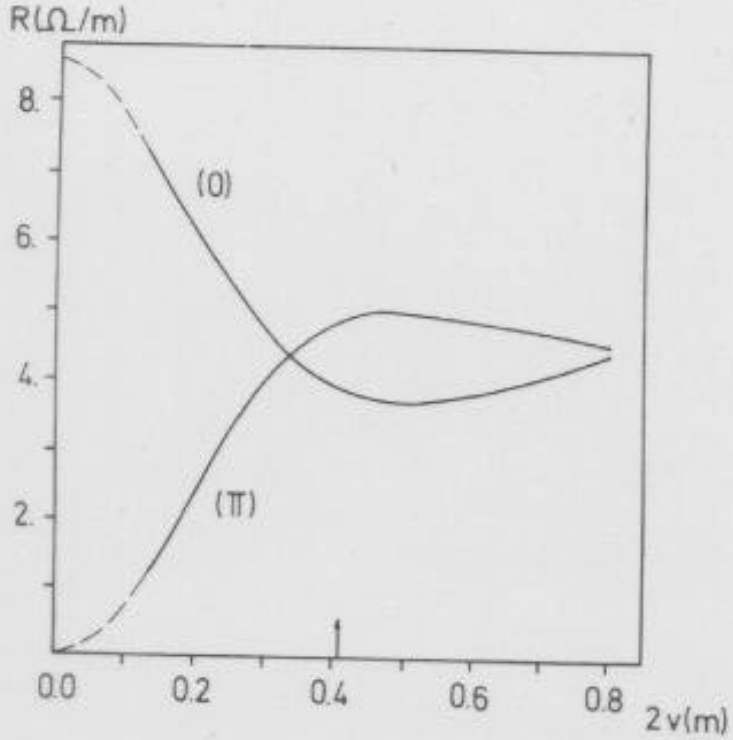
- ✿ System working satisfactorily
- ✿ Without screen
- ✿ Full power / Long pulse / High power density
- ✿ Good day / bad day syndrome (significant dependence on wall / edge conditions)

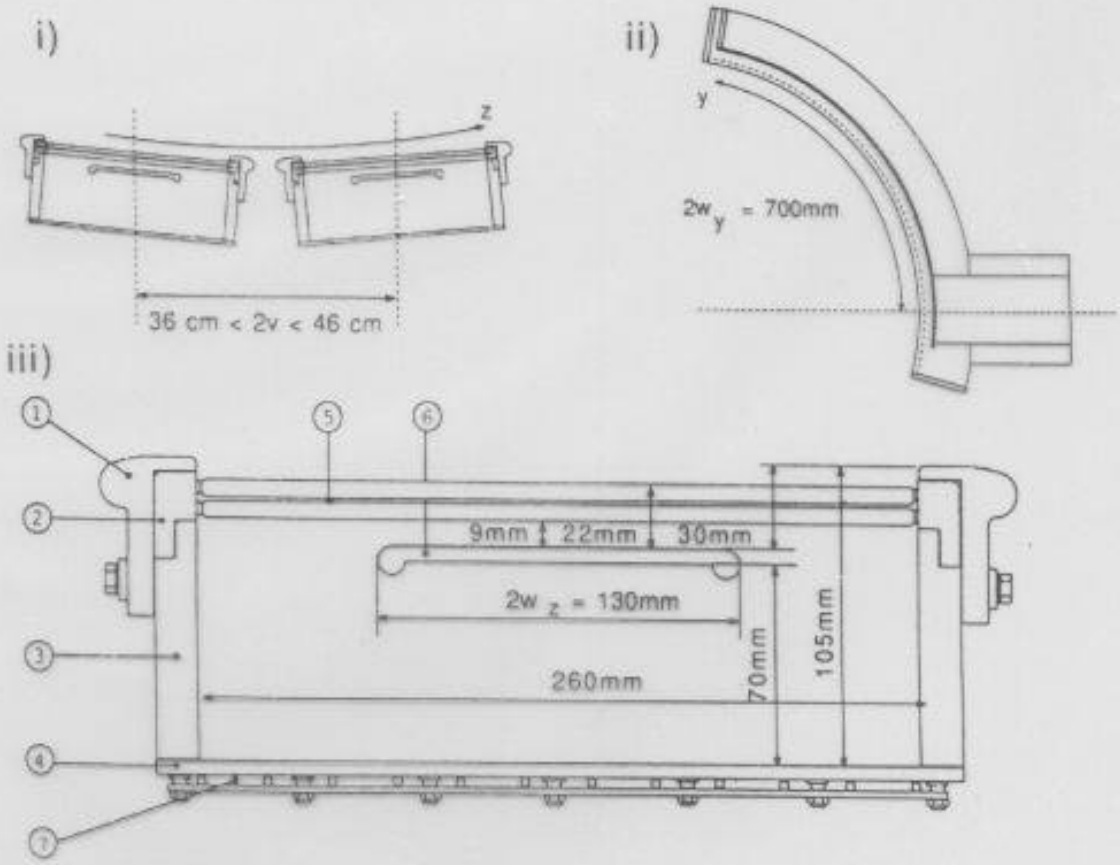





TEXTOR-94
ECRH
GMS
HCN
NBI-2
ICRH-1
B_T
I_P
ICRH-2
CCD
GMS
NBI-1
1
2
3
4
5
6

TEXTOR ANTENNA PAIR





COUPLING : COMPARISON BETWEEN EXPERIMENT AND THEORY ON TEXTOR

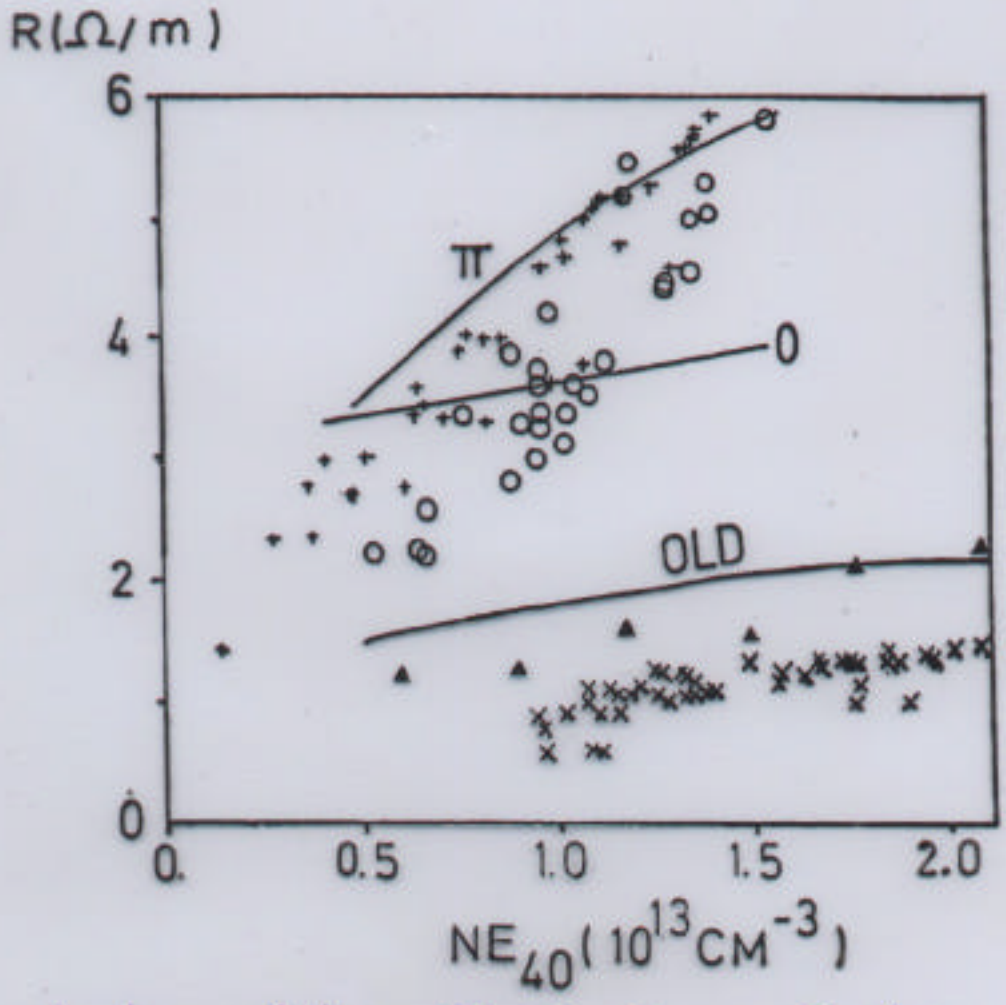
Solid lines : theory

OLD ANTENNA : ▲ Low power (<40W)

× High power (>200kW)

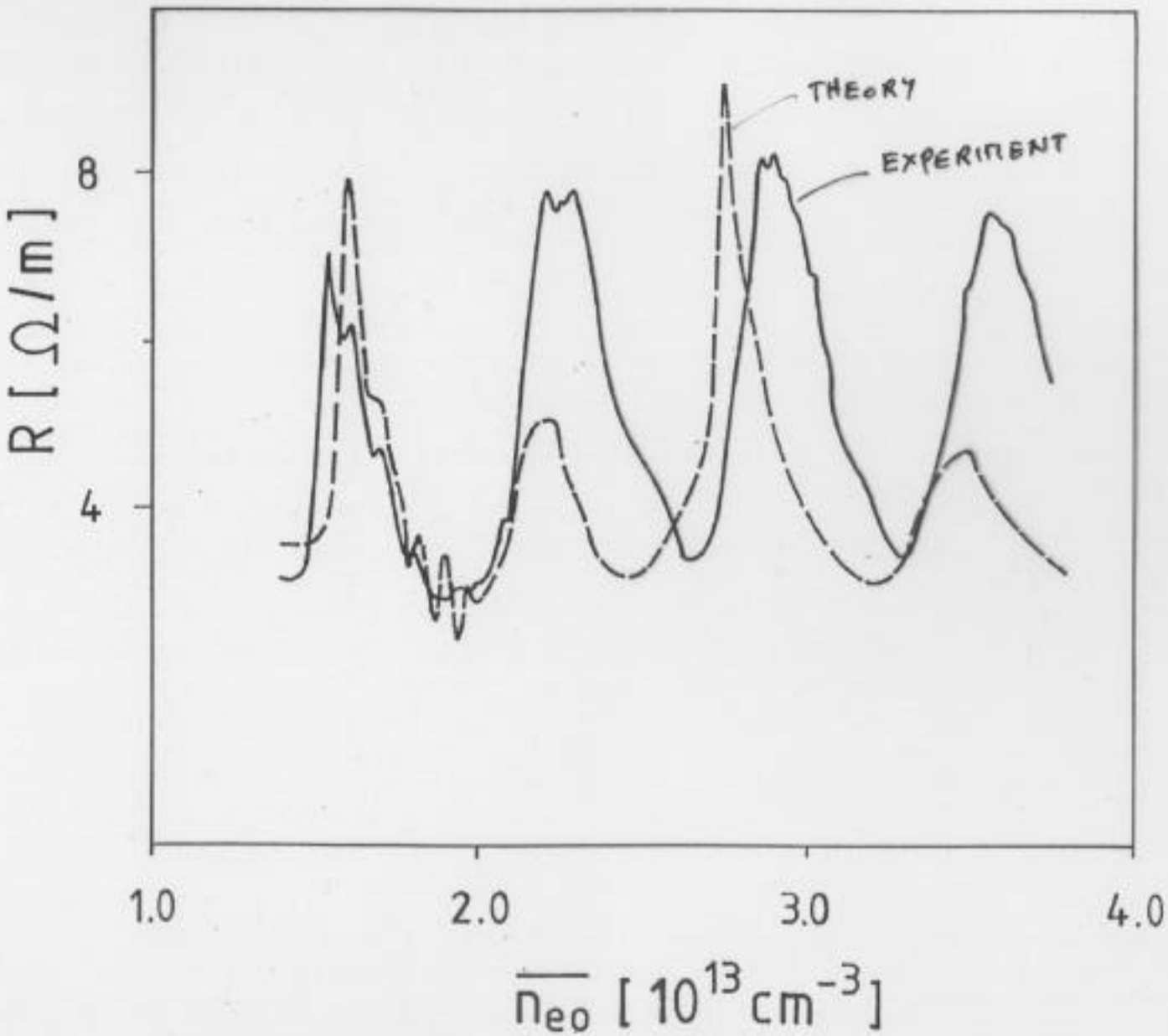
NEW ANTENNAS : o o-o phasing (monopole)

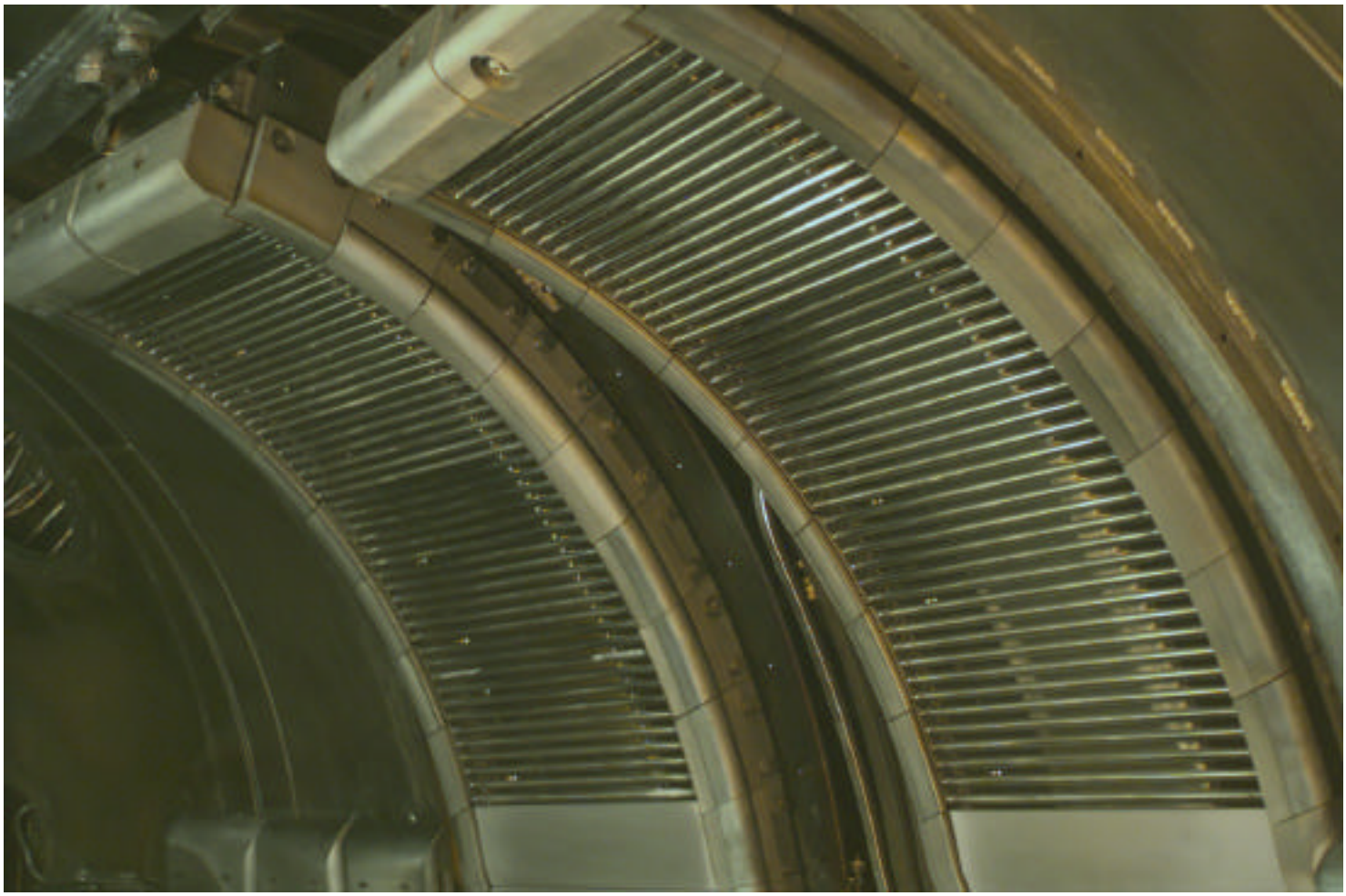
+ o-π phasing (toroidal dipole)



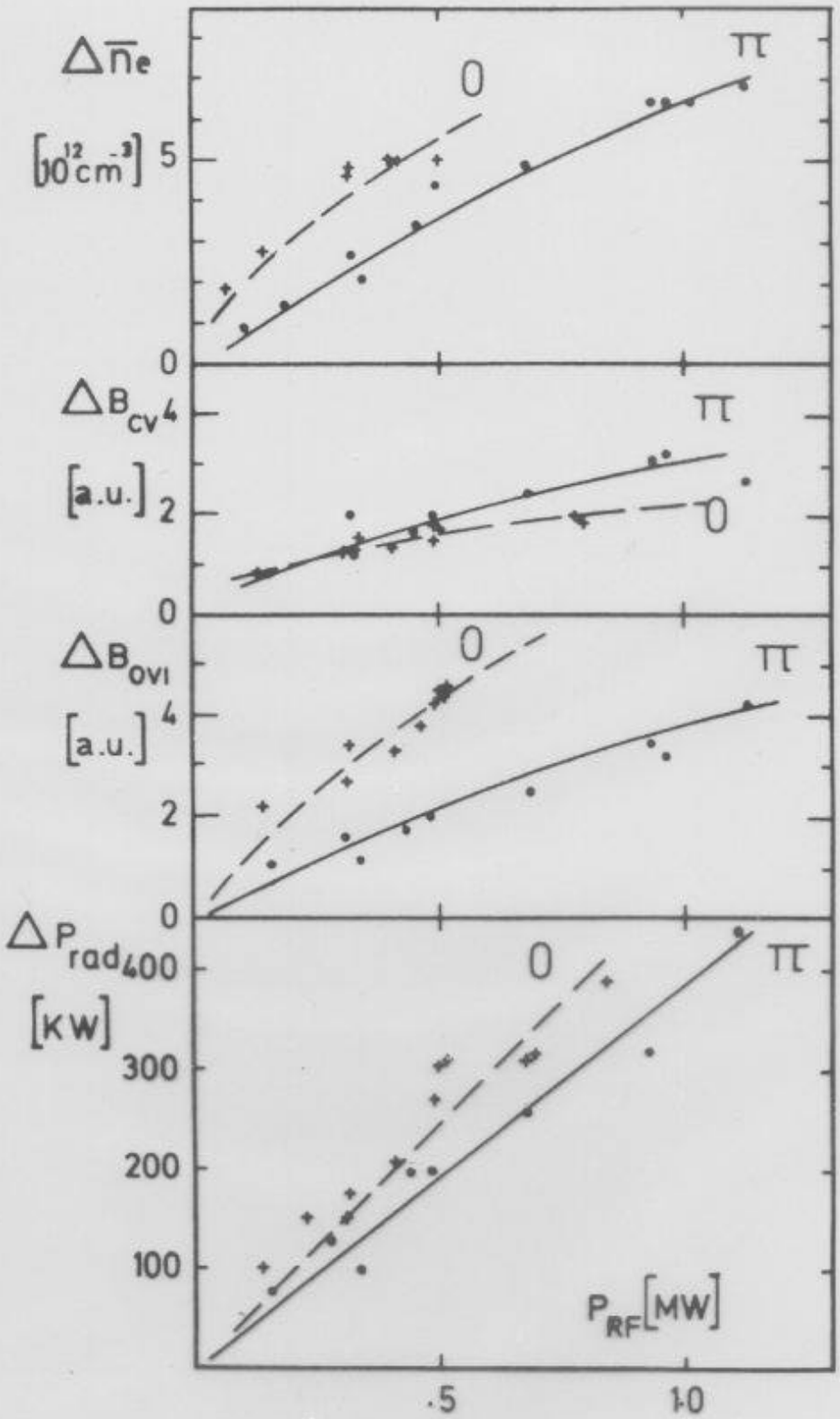
See Beuken, Poster P8 E1 32 on Friday

Global FW resonances at low absorption (TEXTOR)



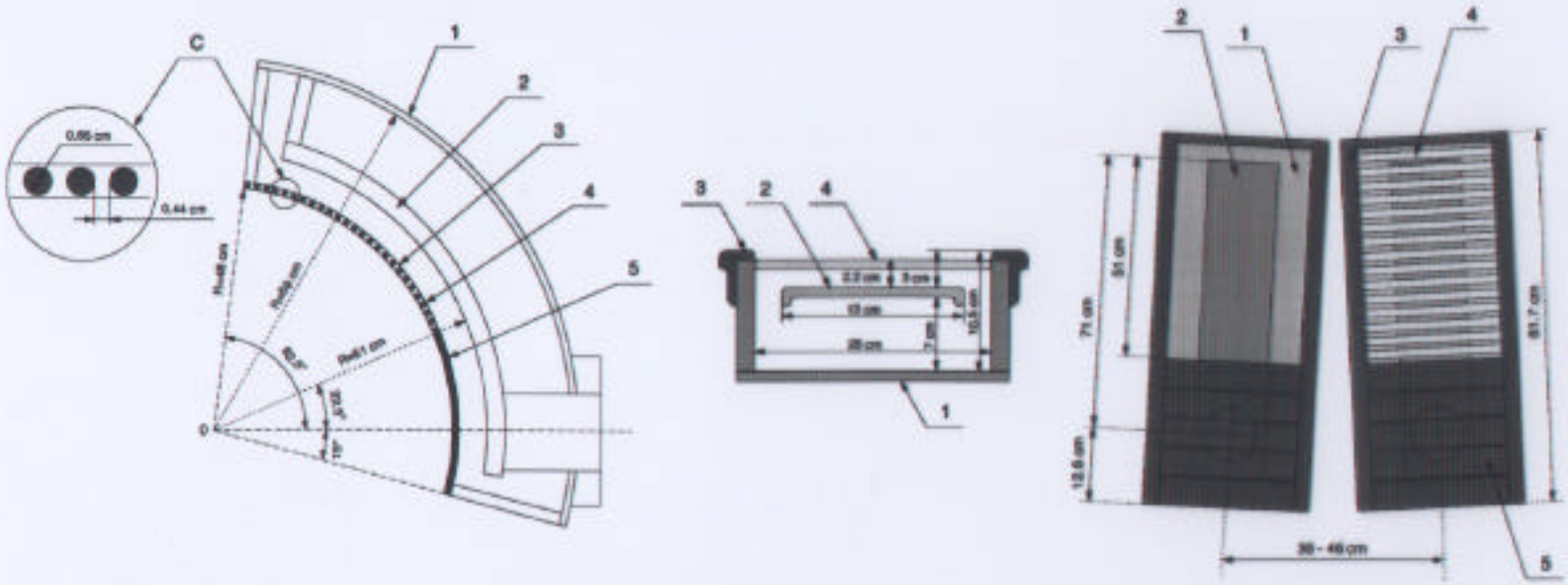


REDUCTION OF WALL INTERACTION DUE TO ICRH WITH π-PHASING

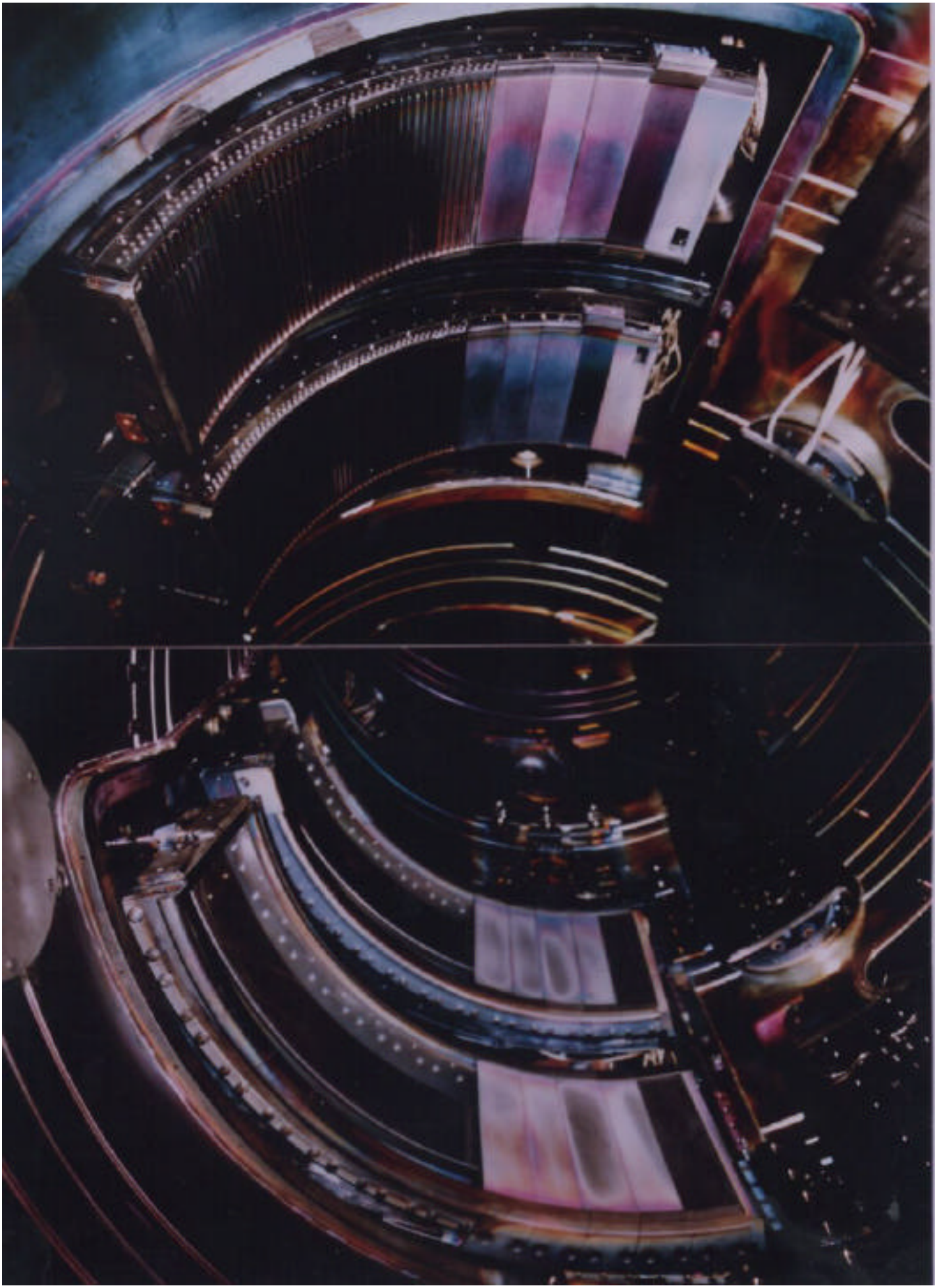


-Increases of density, impurity line brilliance and total radiated power due to ICRH for 0 and π phasing (carbonized wall, $T_L = 400°C$).

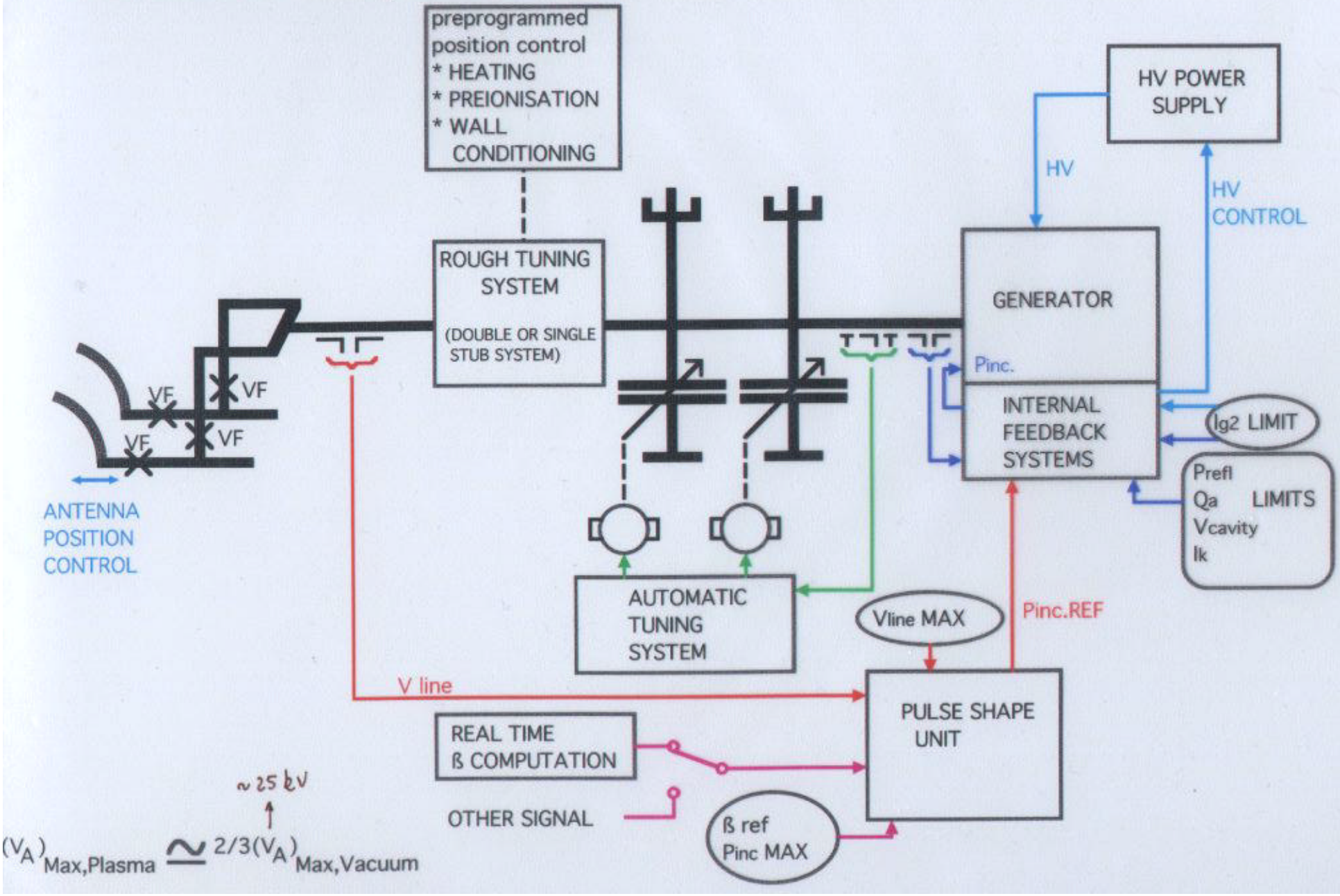
Layout of the TEXTOR-94 shielded and unshielded ICRF antennas



1 - antenna box back plate; 2 - antenna current strap; 3 - graphite antenna side limiter tiles; 4 - antenna Faraday shield (FS) rods; 5 - graphite NBI protection plates.

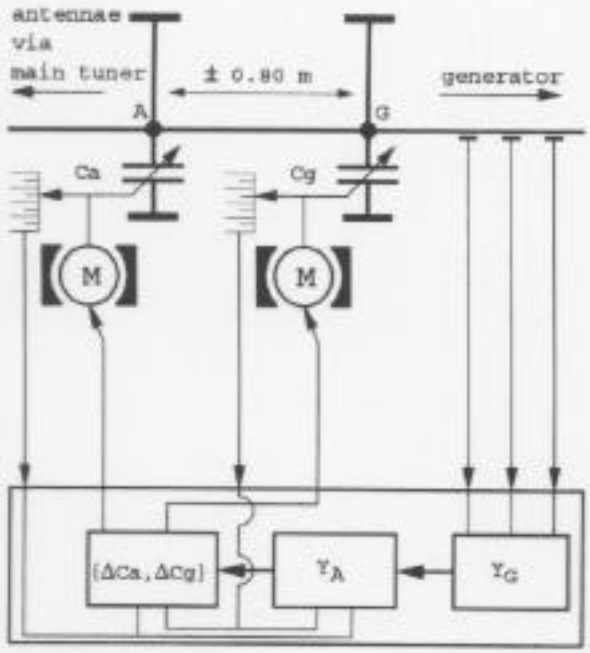


OPERATION AT HIGH γ =Prad/Ptot NEEDS HIGHLY RELIABLE ICRH SYSTEM

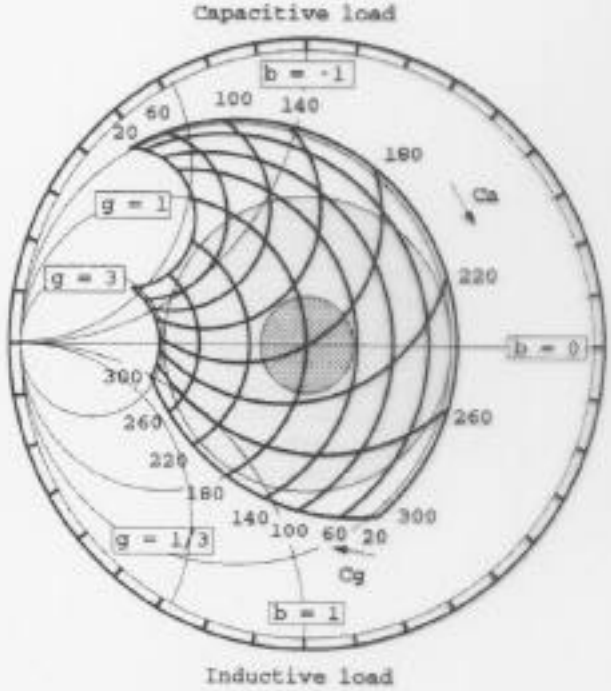


Automatic Tuning System

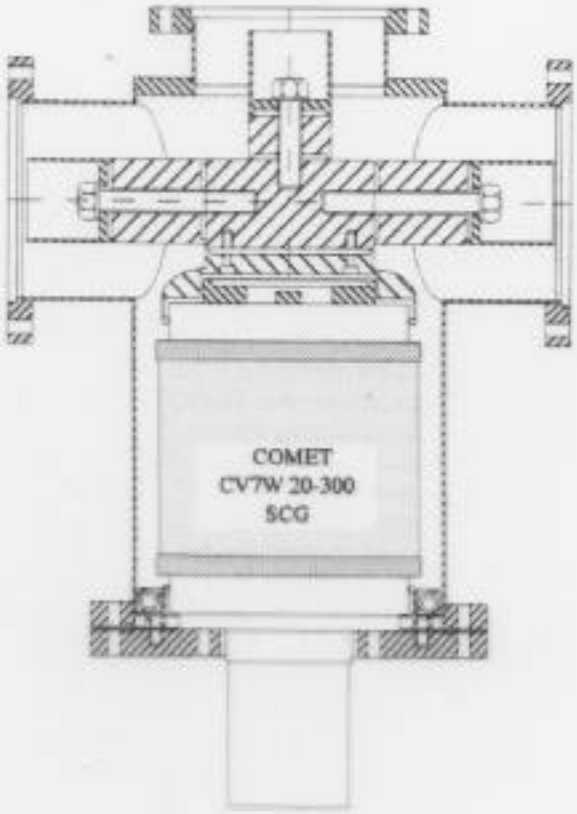
Principle :



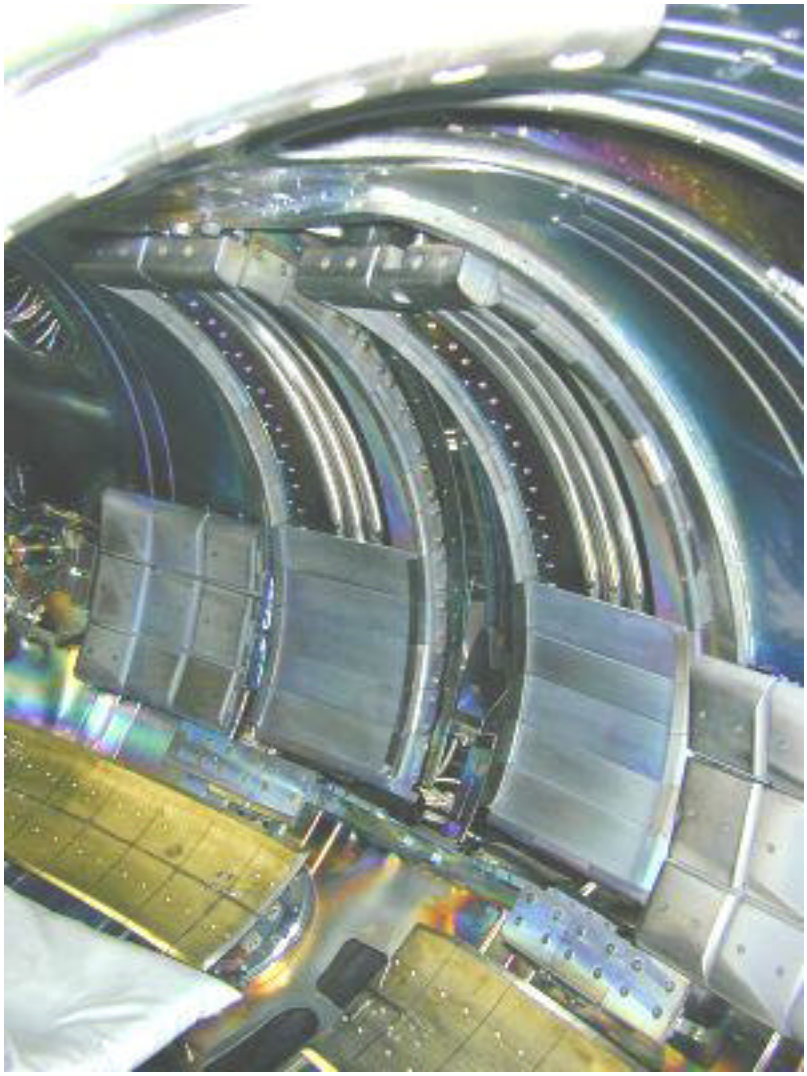
Accessible mismatch region :



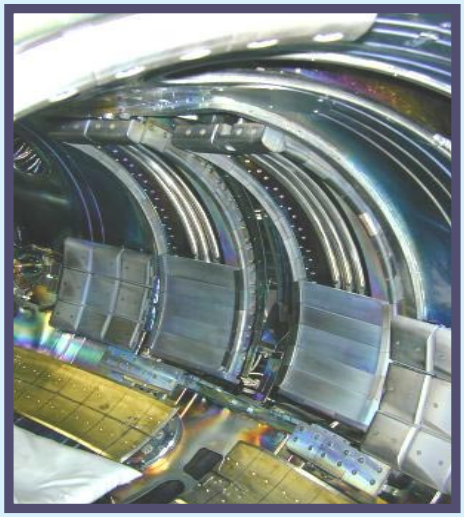
X-junction :



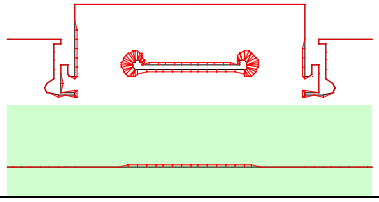
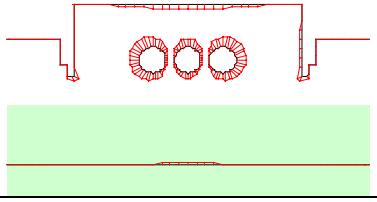
$\tau \cong 150$ ms



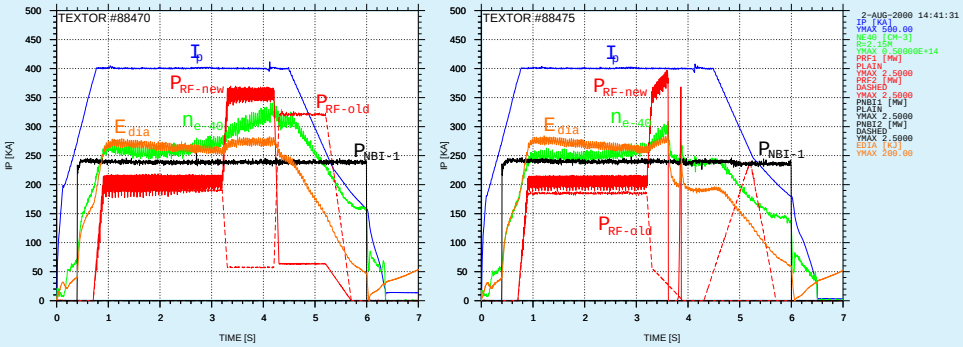
New Low Electric Field ICRH Antenna Test on TEXTOR-94



2-D Manetostatic modelling

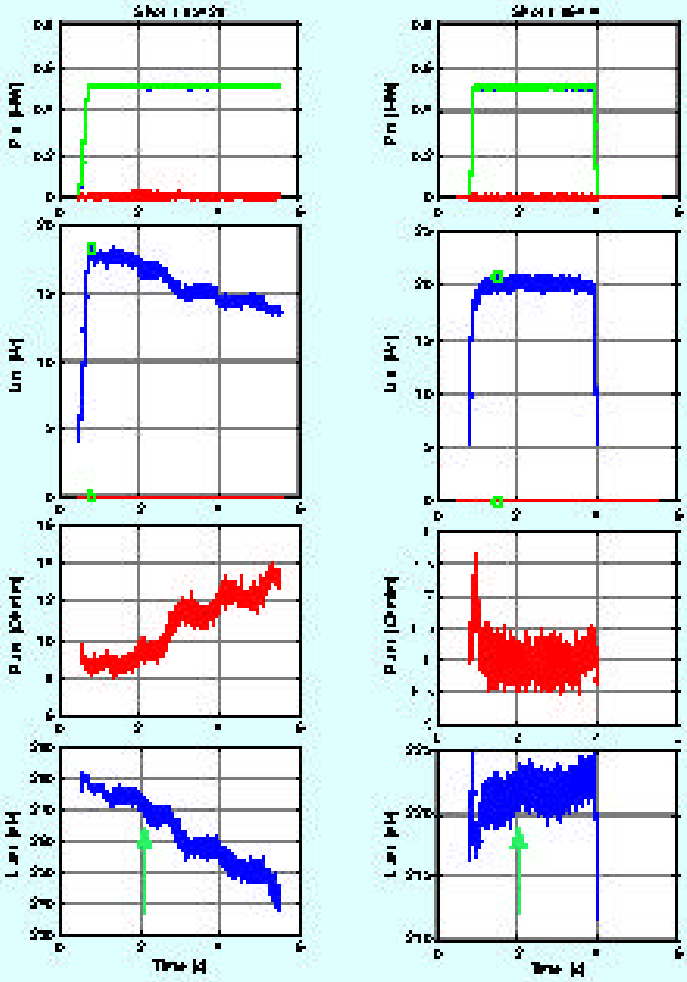
Original Inner Conductors With graphite limiters (FS holder removed)	New inner conductors Graphite limiters removed (extreme case)
	
$P \approx R / (E_{max} L)^2$; $f_{PE} = P_{new} / P_{orgininal}$	
L = 232 nH/m R = 6 Ohm/m E_{max} = 60 m^{-1} (V/m per V on the strap) $f_{PE} \equiv 1$ (definition)	L = 217 nH/m R = 5.3 Ohm/m E_{max} = 37. 7 m^{-1} f_{PE} = 2.6

Test at high RF power



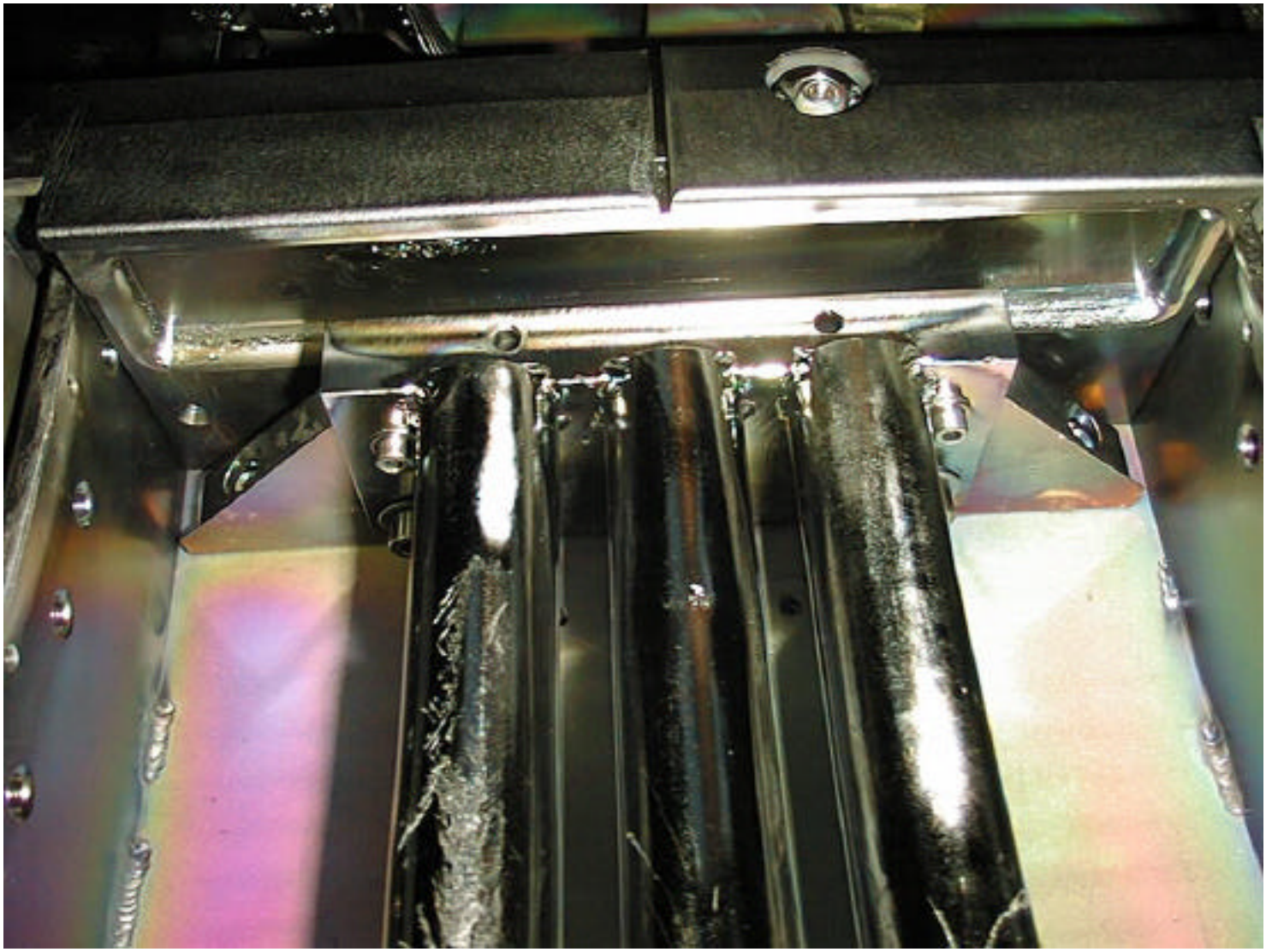
New Low Electric Field ICRH Antenna Test on TEXTOR-94

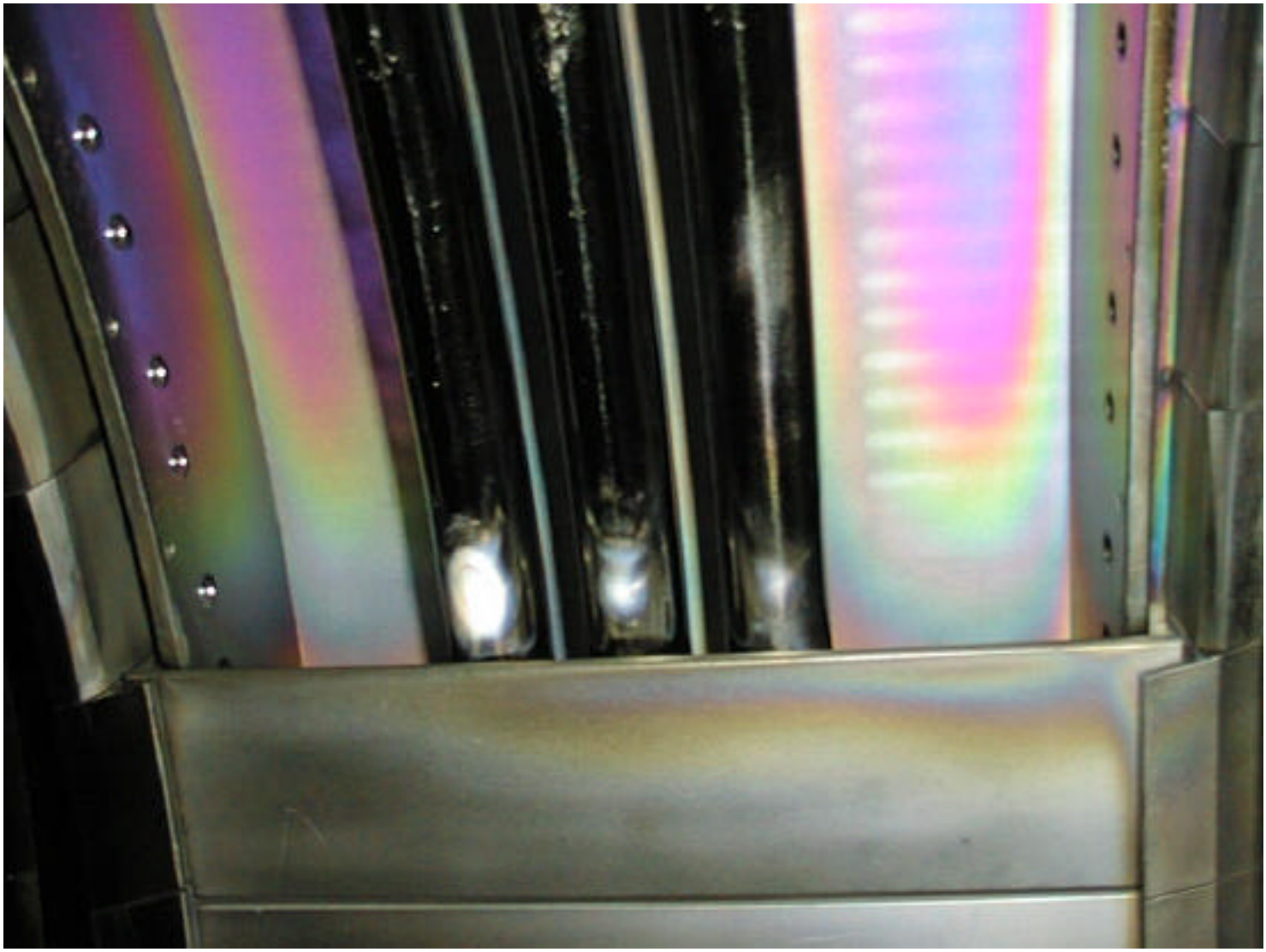
Old ICRH antenna New ICRH antenna



First tests of the new ICRH antenna in vacuum and in plasma ($\omega = 2\omega_{ci}$)

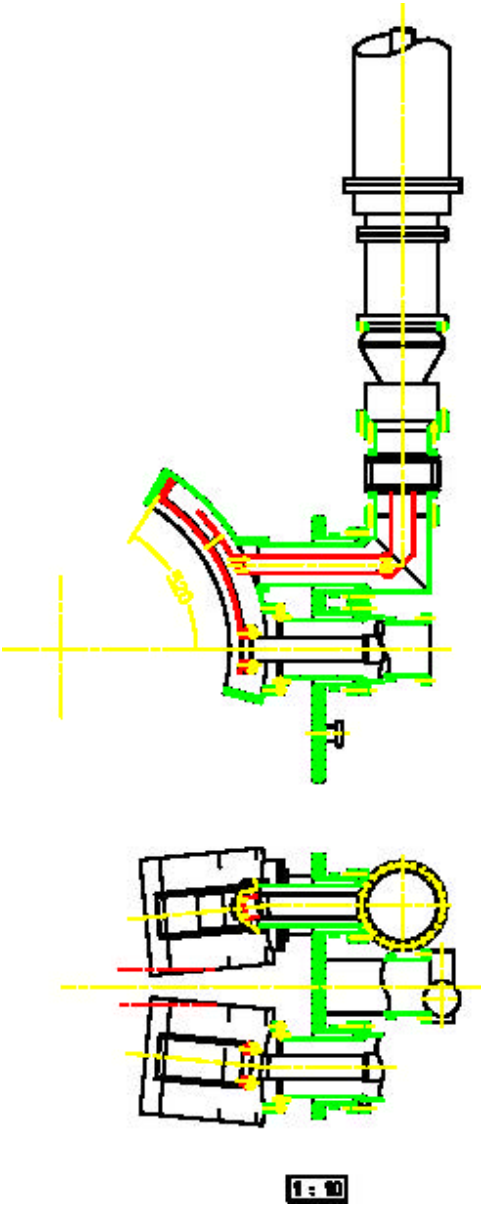
- The expected loss of the antenna-plasma resistance (~35%) and inductance (~18%) are in qualitative agreement with predictions of modelling.
- Reliable antenna-vacuum conditioning of the new antenna with optimized transmission line is possible at RF power increased by ~50%.
- Operation of the new antenna at up to P_{RF}=1.95 MW in $\omega = 2\omega_{ci}$ heating scenario has been achieved so far.





TEXTOR-94

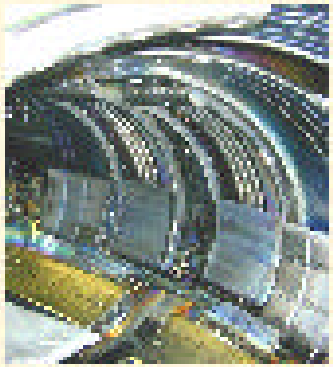
New ICRH Antenna for TEXTOR with DED Running (from ~May 2002)



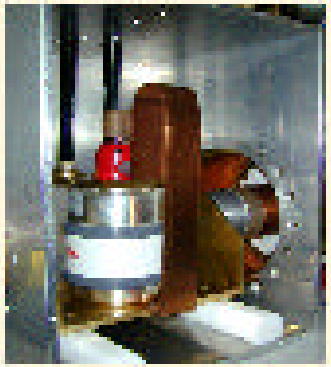
ICRF Technologies

RF Antenna

New low electric field ICRF central conductors for TEXTOR-94



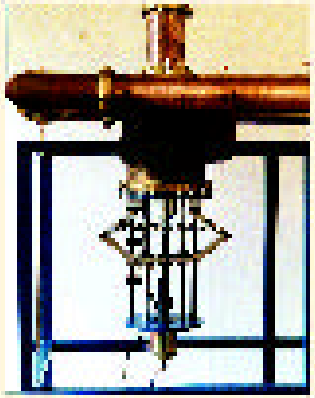
2nd Harmonic Filter



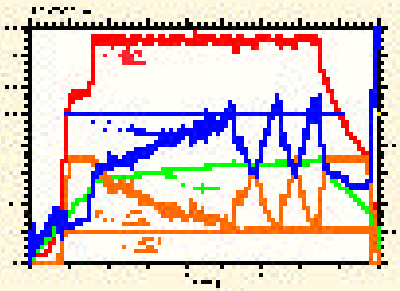
Filter box to remove the harmonics from the transmission line of a generator of 2 MW operating at a frequency between 26 and 39 MHz on TEXTOR-94

Autotuning system

System to adapt in real time the impedance of the generator to the antennas. The system is composed of 2 variable capacitors and 2 stubs in parallel. The response of the system is typically 20 ms for VSWR of 3.



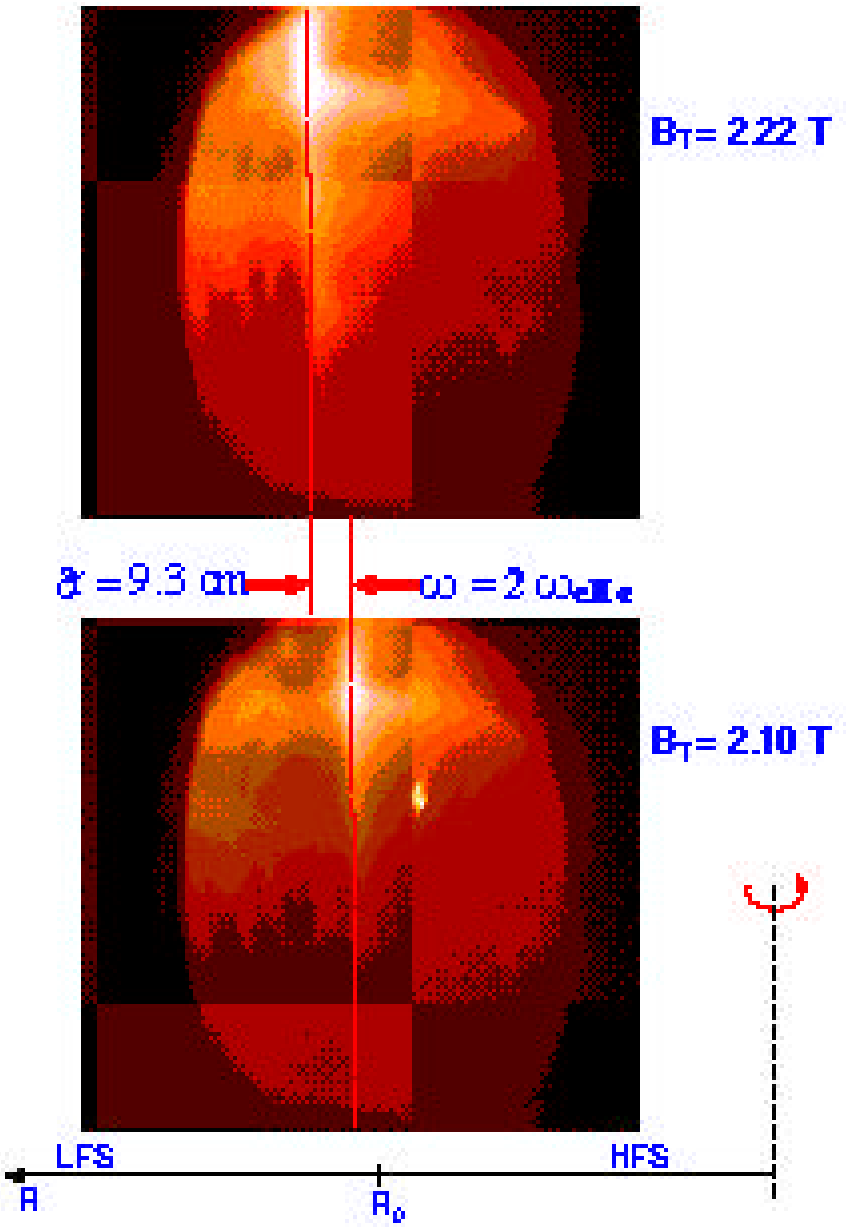
Feedback control of plasma energy



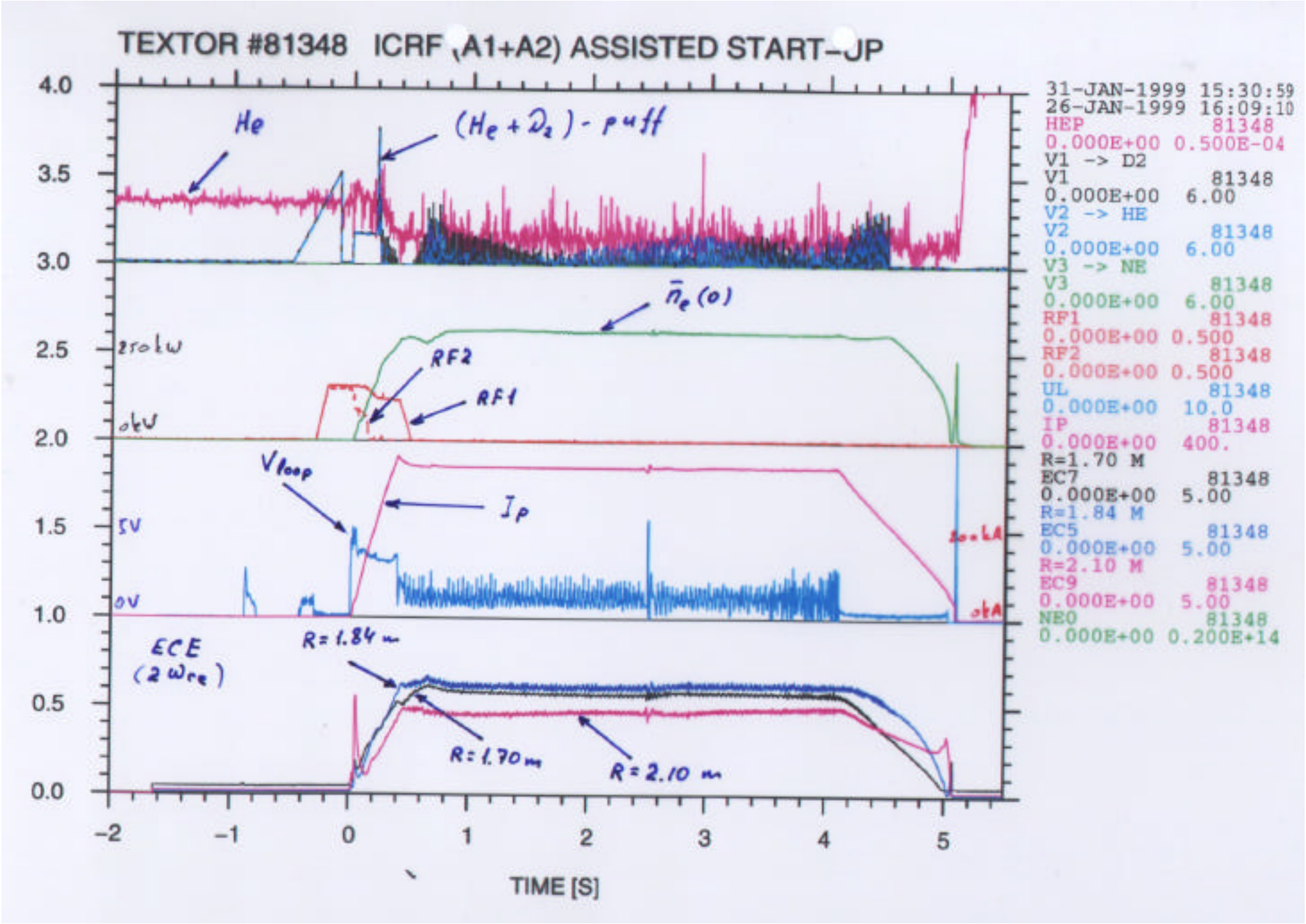
A PC computes in real time the diamagnetic energy (E_{dia}) of the plasma of TEXTOR-94 and modifies the power of the ICRH system to keep the energy constant

ICRF helium plasma in TEXTOR-94:

bright vertical radiating layer correlates with the position of $\omega = 2\,\omega_{cHe} = \omega_{cH}$ cyclotron resonance



A1 (w/o FS) and A2 (with FS) - in phase, f1=f2=32.5 MHz, $P_{RF1}=P_{RF2}$=200 kW, p(He)=1x10^{-3} mbar, $n_e(0)$=9x10^{11} cm^{-3}.


TEXTOR #81348 ICRF (A1+A2) ASSISTED START-UP
He
(He + D2) - puff
ne(0)
250kW
0kW
RF2
RF1
Vloop
Ip
5V
0V
500kA
0kA
ECE
(2 ωce)
R=1.84 m
R=1.70 m
R=2.10 m
TIME [S]
31-JAN-1999 15:30:59
26-JAN-1999 16:09:10
HEP 81348
0.000E+00 0.500E-04
V1 -> D2
V1 81348
0.000E+00 6.00
V2 -> HE
V2 81348
0.000E+00 6.00
V3 -> NE
V3 81348
0.000E+00 6.00
RF1 81348
0.000E+00 0.500
RF2 81348
0.000E+00 0.500
UL 81348
0.000E+00 10.0
IP 81348
0.000E+00 400.
R=1.70 M
EC7 81348
0.000E+00 5.00
R=1.84 M
EC5 81348
0.000E+00 5.00
R=2.10 M
EC9 81348
0.000E+00 5.00
NEO 81348
0.000E+00 0.200E+14

Gallery of Fame

Record Shots TEXTOR ICRH

shot	# straps	Pgen1 MW	Pgen2 MW	Ptot MW	flat top s	Etot MJ	limit
T38568	4	2.0	2.0	4.0	0.6	3.55	-
T44751	2	1.5	1.5	3.0	0.4		-
T44752	2	±1.7	±1.7	3.4	0.4		matching
T57741	2	1.4	-	1.4	2.3	3.2	(conditioning)
T79888	**4**	**1.9**	**1.9**	**3.8**	**3.5**	**14.8**	**-**

T79888 :

95 % of installed power

(20 % of installed energy (4MW,18s))

Problems that remain :

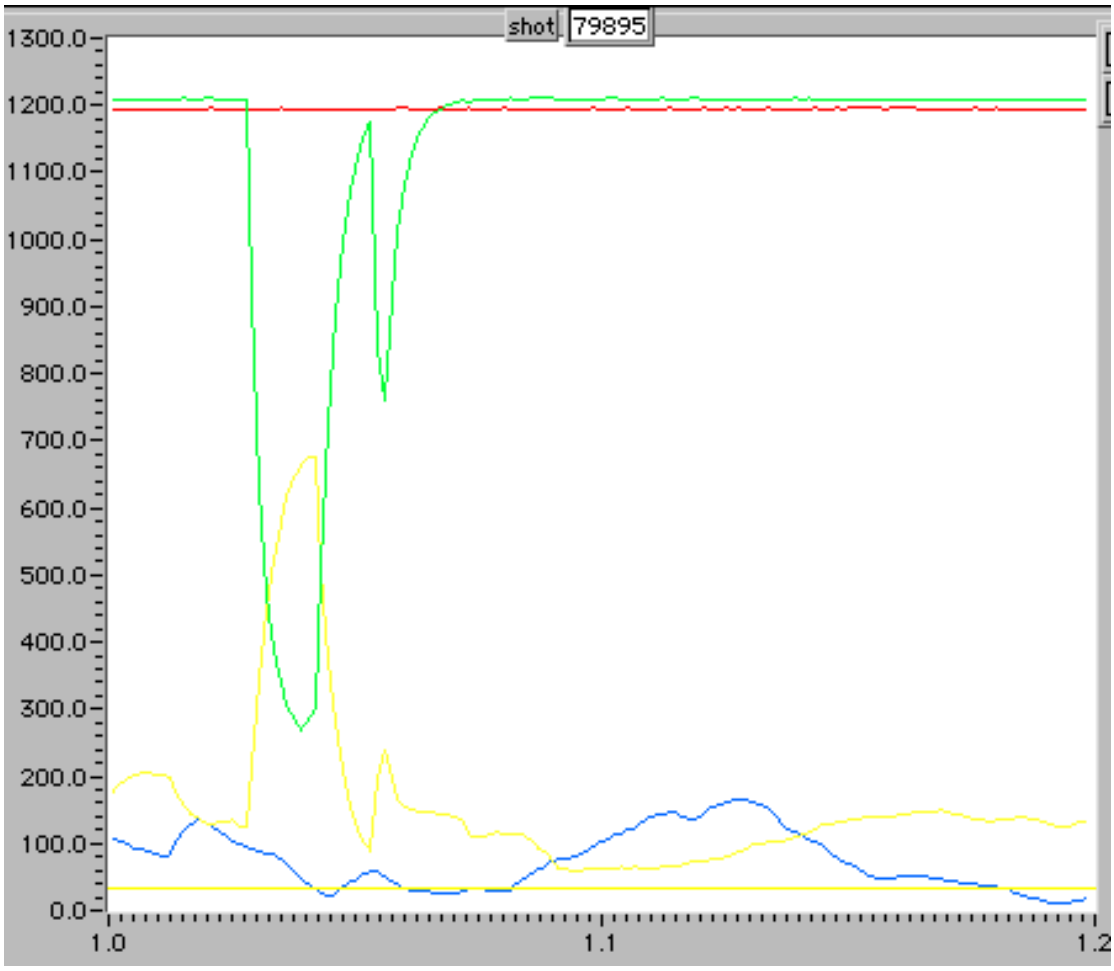
• **Why did Generator 2 with antennas 10-11 work so well ??**

➔ **measure S12 of generator 2 and compare with generator 1**
➔ **calibrate power of generator 2**
(reading could be somewhat optimistic)

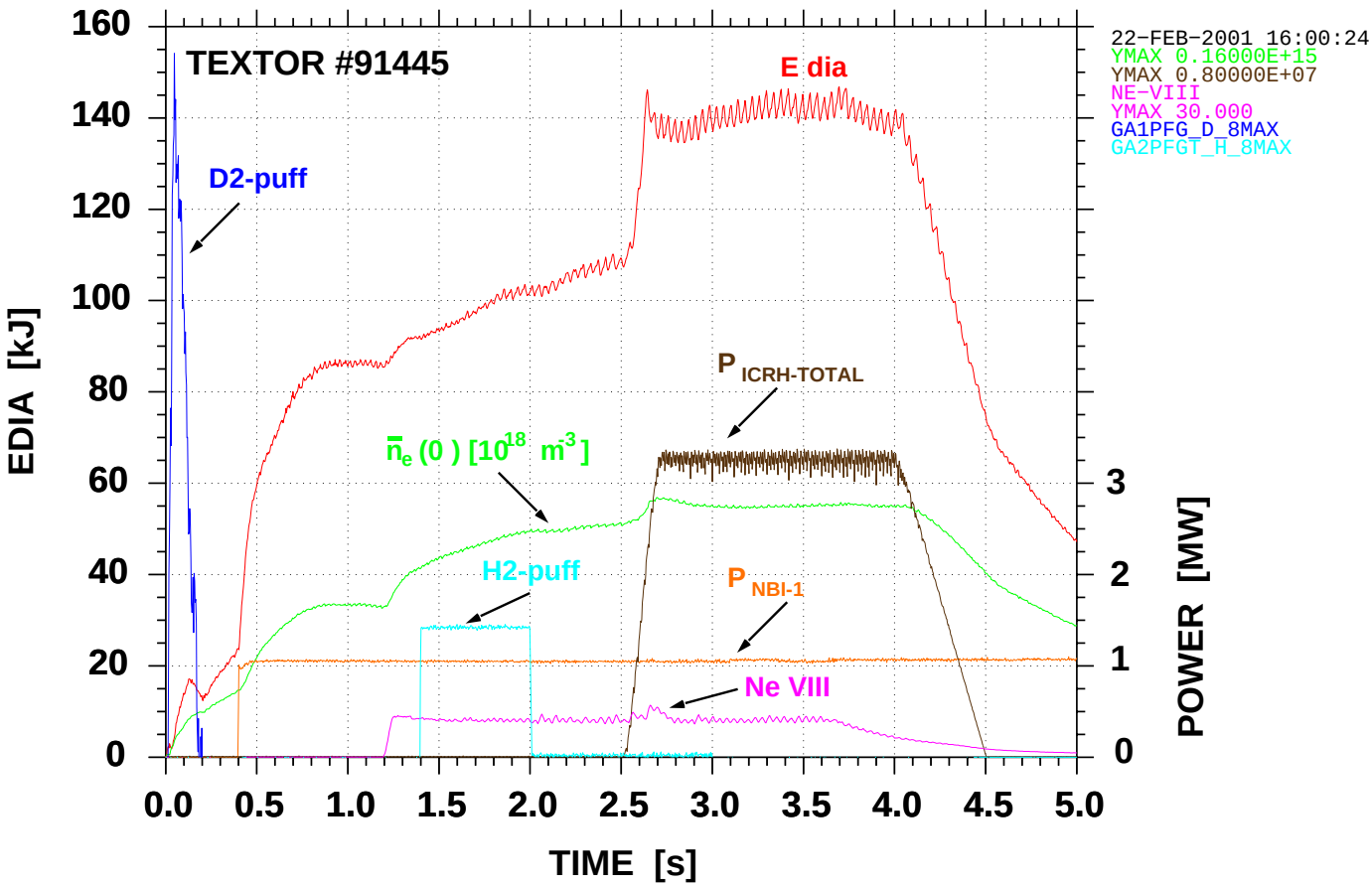
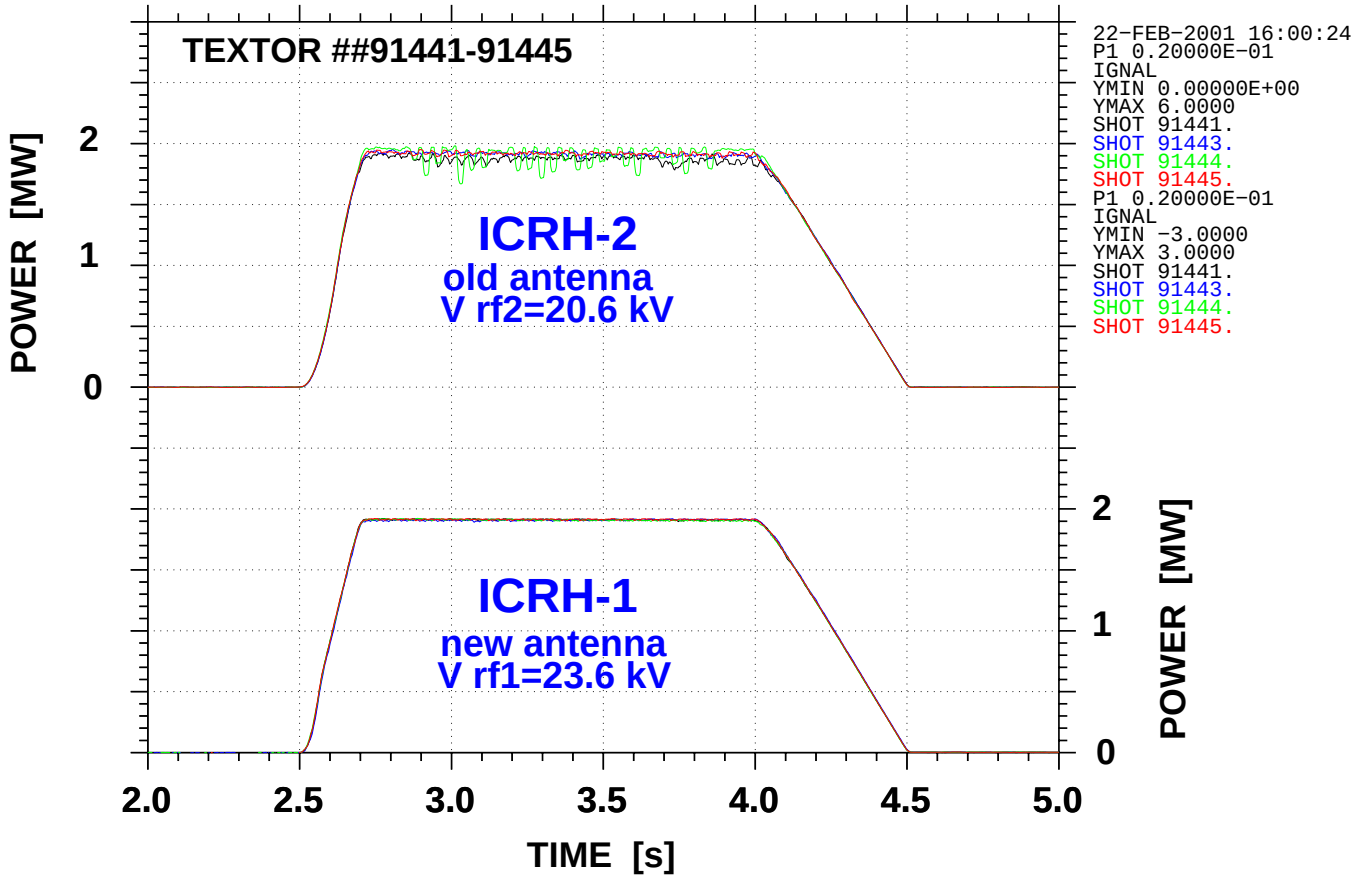
• **B_t & I_p reversed :**

problems with Generator 1 :

rapid large variations reflected power
-> effect of drift of particles and screen ?



Tests of ICRH Antennas With Total Installed Power



Reliability of TEXTOR ICRH Antennas Operation at Full Installed Power 2x2 MW