Wall Conditioning Strategy for Wendelstein7-X

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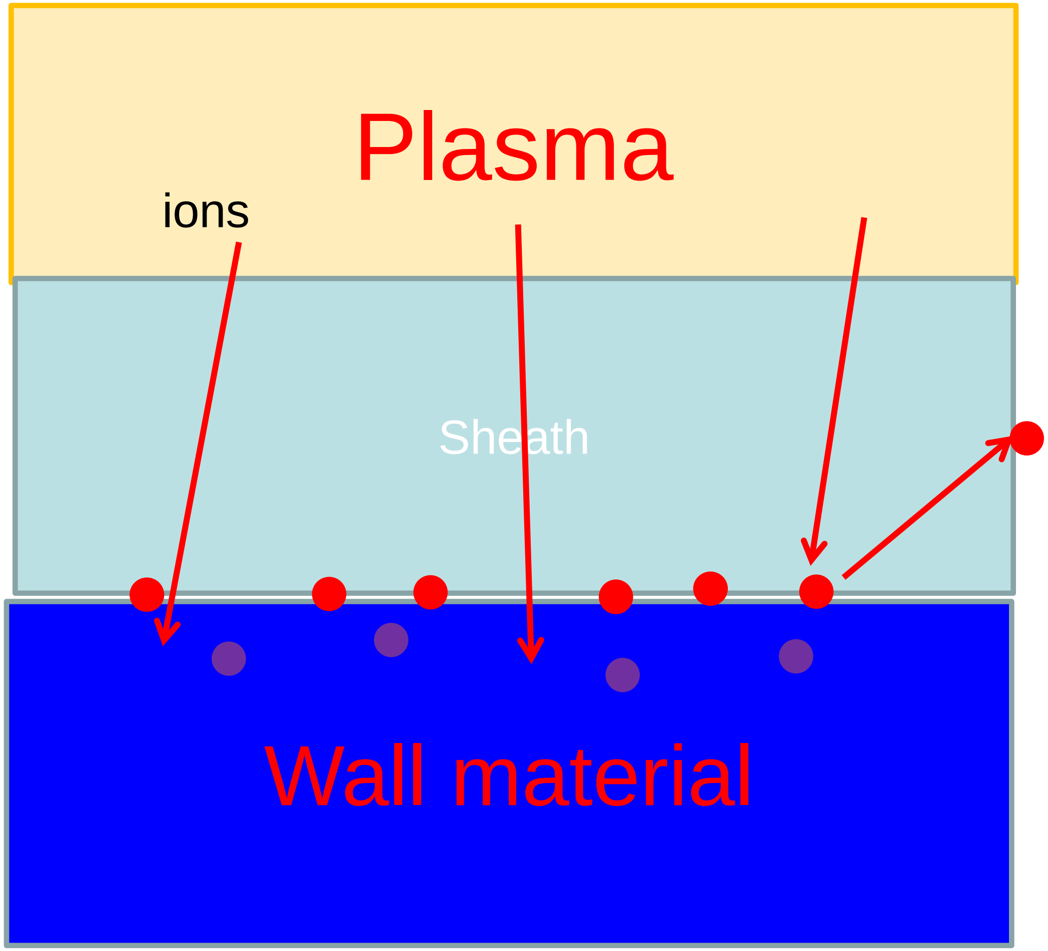
Outline

1. Physics background
2. Experience from different experiments (LHD, Wega. Tore Supra)
3. Strategy for W7-X and proposal for LHD experiments

Plasma Wall Interaction

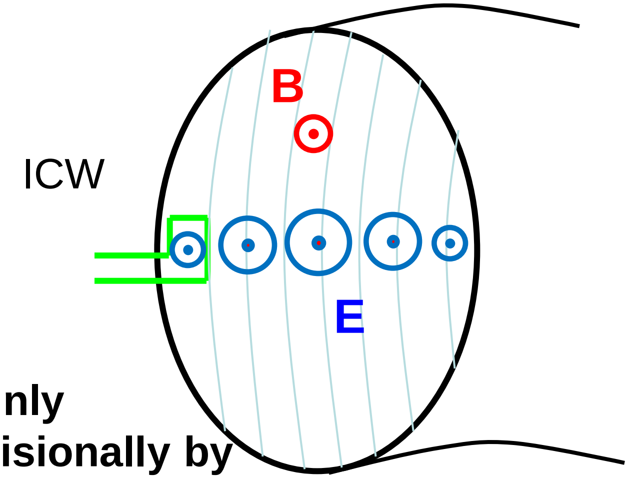


Ion acceleration by
sheath potential ≈ kT_e/e

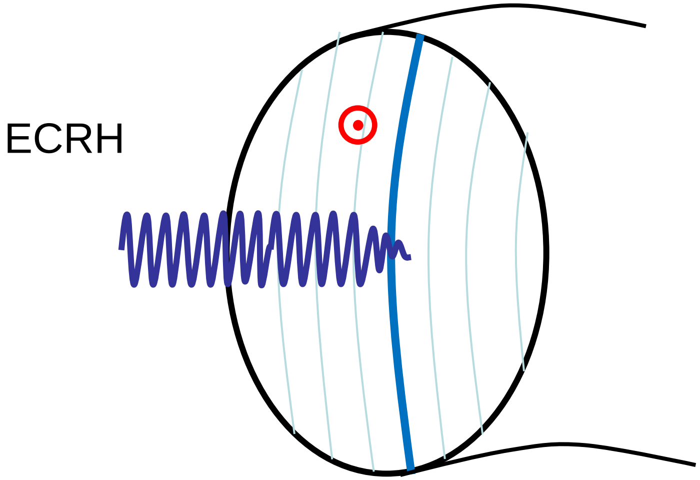
Impurities at surface

Hydrogen (Deterium)
desorbed (replacement)

ICW versus ECRH: Tokamak

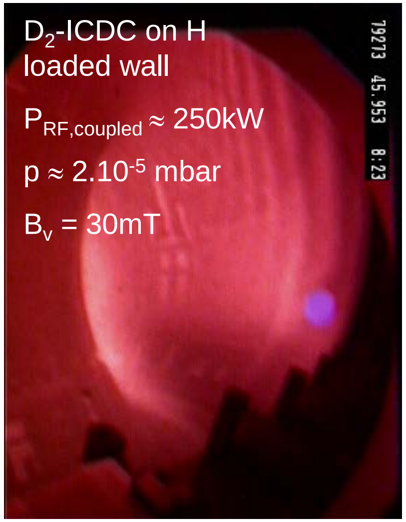


RF power mainly absorbed collisionally by electrons.
Density profile represents electric field profile.



Density profile represents dominating cyclotron absorption

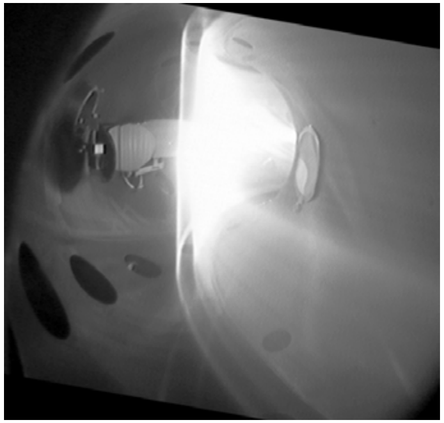
JET ICW in deuterium


D_2-ICDC on H loaded wall

$P_{RF,coupled} \approx 250kW$

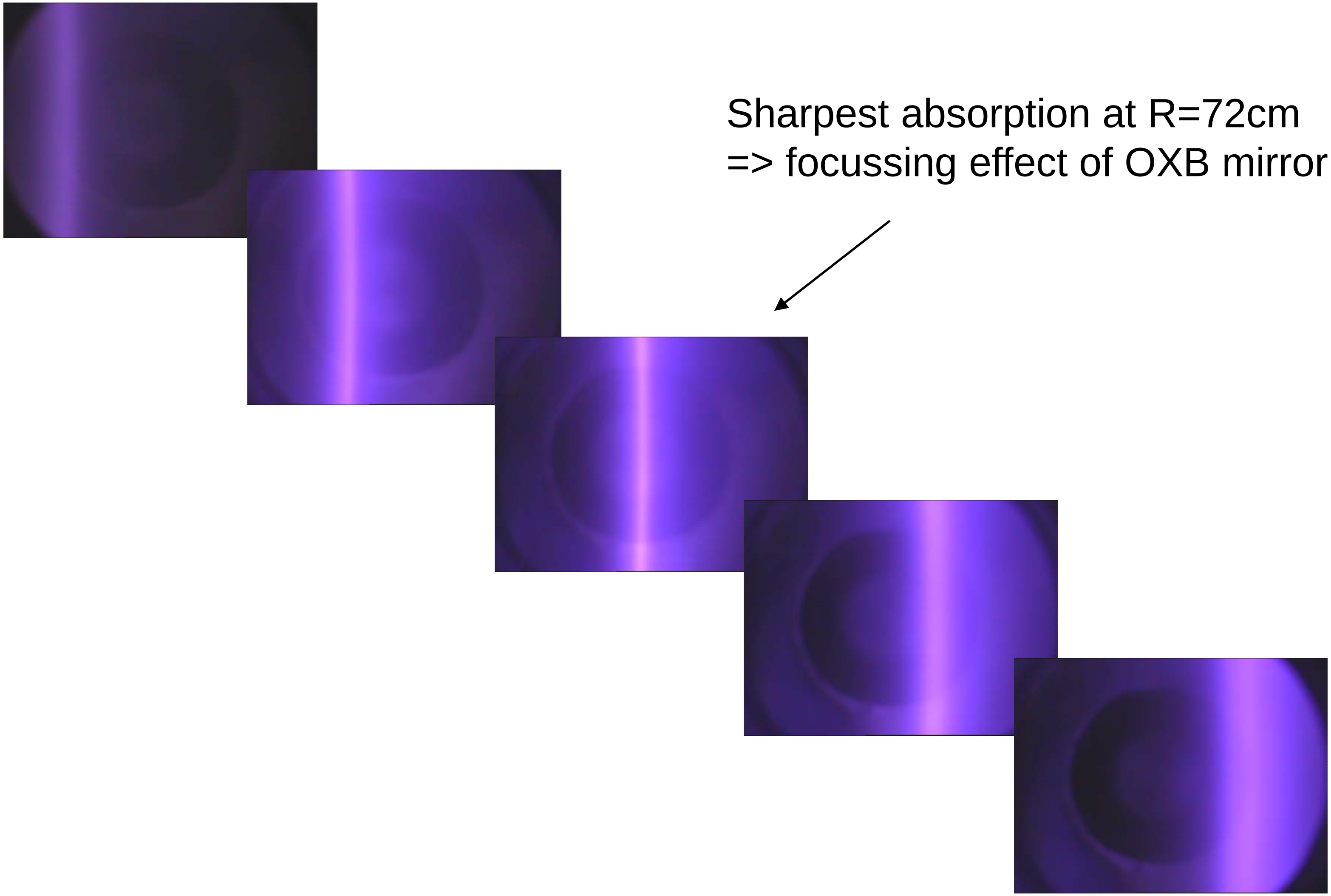
$p \approx 2.10^{-5}$ mbar

$B_v = 30mT$



28 GHz X2 at B= 0.5 T toroidal field only

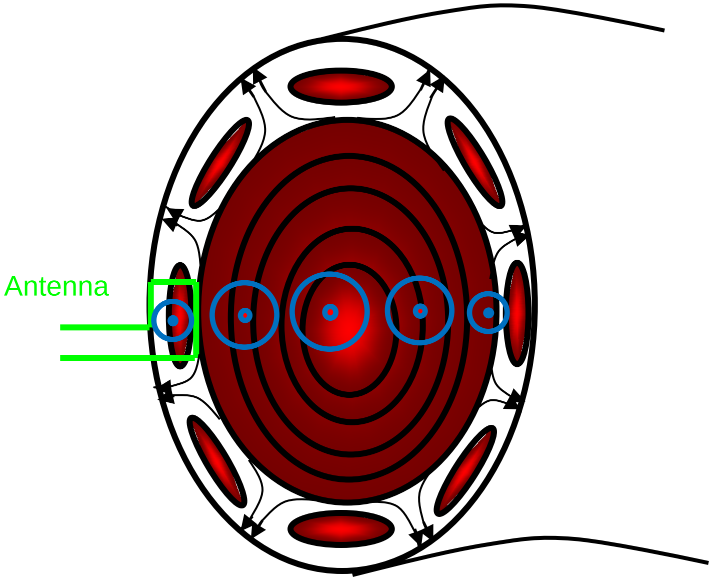
Field Strength Variation from 0.44 => 0.52T: #27447



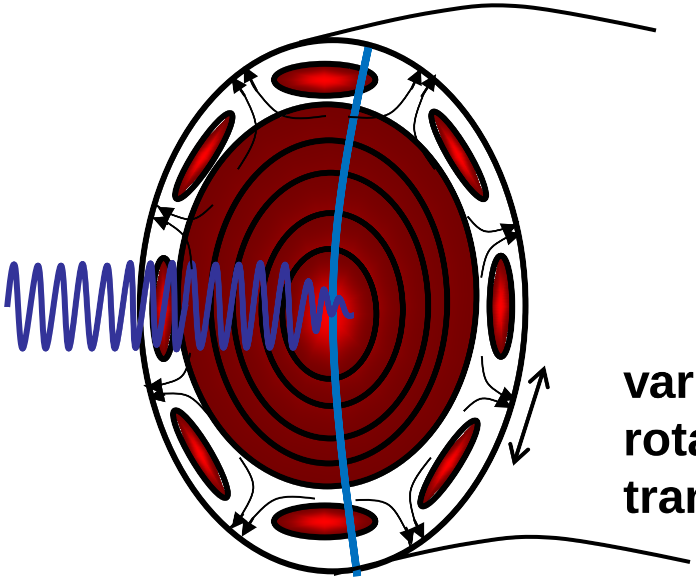
Sharpest absorption at R=72cm
=> focussing effect of OXB mirror system

ICW versus ECRH: Stellarators

ICW



ECRH



variation of rotational transform

Density profile represents confinement, but resistive absorption is low.

Density profile represents Confinement, but EC-absorption is high.

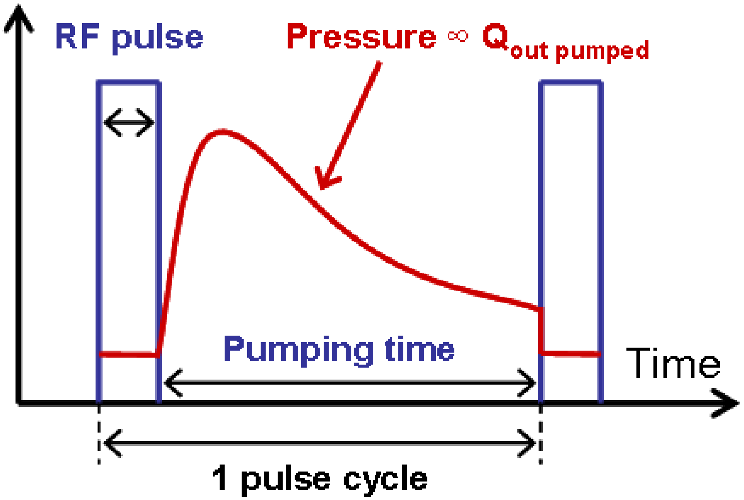
Plasma wall interaction at strike point!

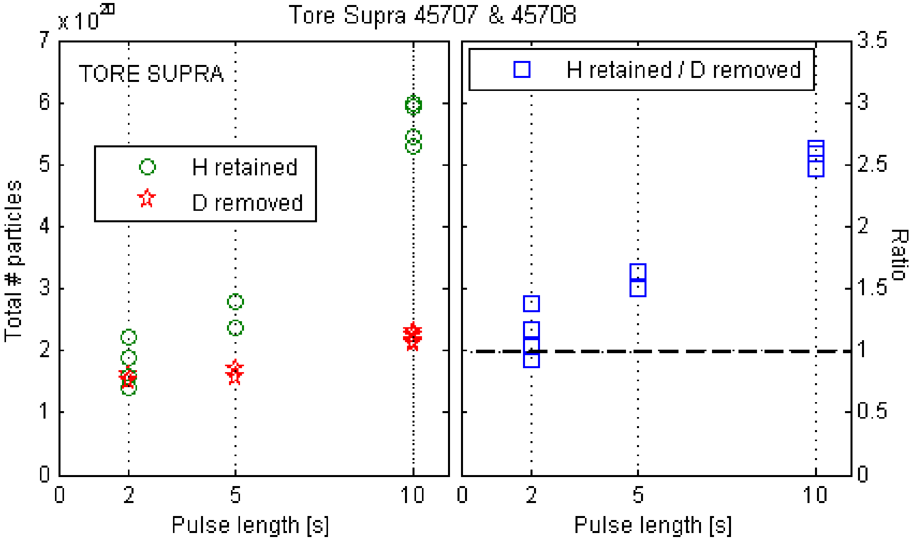
Wall Conditioning Efficiency

Limit retention by optimizing RF duty cycle

- Probability to remove wall desorbed particles from vessel during RF pulse ≈ 0
    - High ionization probability (> 99%)
    - Char. pumping time constant (6-8s) > wall desorption (1-3s) >> collision time (10-100ms)
- Wall flux retention only occurs during RF pulse

→ Include pumping time (no plasma) to recover particles and to avoid retention





H_2-ICDC on D loaded wall

Total pulse cycle = 40s

6/19

Ideal ratio = 1 obtained both on TORE SUPRA and on TEXTOR

- Optimal pumping time ≈ 3x Char. pumping time constant (3x 6-8s)

With courtesy of Tom Wauters 21/02/12

ICW Extrapolation to W7X

- Conditioning aims
  - ✓ Recover from radiation collapse
  - ✓ Wall desaturation
  - ✓ Impurity removal
- Application
  - – Inter-pulse ICDC (10-15min)
- Parameters
  - – Pulsed RF operation: 2s pulses, 3xτ_S pumping time
  - – p_{He}= $2\cdot10^{-4}$mbar, P_{RF} = 250-350kW,
  - – $n_e = (1\text{-}5)\cdot10^{17}\text{m}^{-3}$, T_e = 3-5eV
- Extrapolated efficiency
  - – 435s procedure for wall desaturation
  - – Removal of 0.3 H monolayers (from TORE SUPRA)

- Conditioning aims
  - ✓ Control isotopic ratio
  - ✓ Impurity removal
- Application
  - – Overnight ICDC (hours)
- Parameters
  - – Pulsed RF operation: 2s pulses, 3xτ_S pumping time
  - – p_{D2}= $2\cdot10^{-4}$mbar, P_{RF}=100-150kW
  - – $n_e = (1\text{-}5)\cdot10^{16}\text{m}^{-3}$, T_e = 3-5eV
- Extrapolated efficiency
  - – 435s procedure for isotope exchange
  - – Removal of 1.7 H monolayers (from TORE SUPRA)

Easily achievable by ECRH

With courtesy of Tom Wauters 21/02/12

Comparison

	W7-X OP1	LHD	WEGA
Heating	**ECRH** 8 MW, cw. NBI 5 (10 MW) 10 s ICRH ? (0.33MW/m^{-3})	**NBI** 15 MW ,10 s ICRH 2.7 MW (0.4 MW cw) ECRH 2MW, 3s (0.4 MW cw)	**ECRH** 10 kW cw LH (2.45 GHz) 26 kW cw (0.36MW/m^{-3})
Vessel surface	SS/ Graphite	SS/ Graphite	SS
Baking	150° c	95°c	<90° c (Discharge heating)
Cleaning	GD , ECRH, ICW?	GD (He, Ne, H), 2.45 GHz ECRH, ICW (since 2005)	ECRH (28 GHz) 2.45 GHz (He, Ar) GD, ICW (3-20 MHz) prepared
Hydrogen removal	ECRH ?	NBI recovery discharge, ICW (He)	ECRH (He)

LHD Experience

1. before the beginning of an experimental campaign

- 1 week of baking ~95°C!
- Ne GD for 1 day
- He and H_2 GD for several days
- Boronization

2. during an experimental campaign

- 2 h of He GDC after high-density experimental day
- baking ~95°C! every weekend.
- Ti coating conducted, if strong hydrogen control is necessary, but the effect is only temporary
- Additional boronization conducted, if necessary for recovering the wall condition from accidental contaminations such as an air leak

3. loss of density control

- ECRH/NBI recovery discharges with no gas inlet.
- ECRH/ICW discharge in He. (10-60) ×10s
  He-GD is 9× more effective than ICW!

WEGA Experience

1. After vacuum vessel opening.

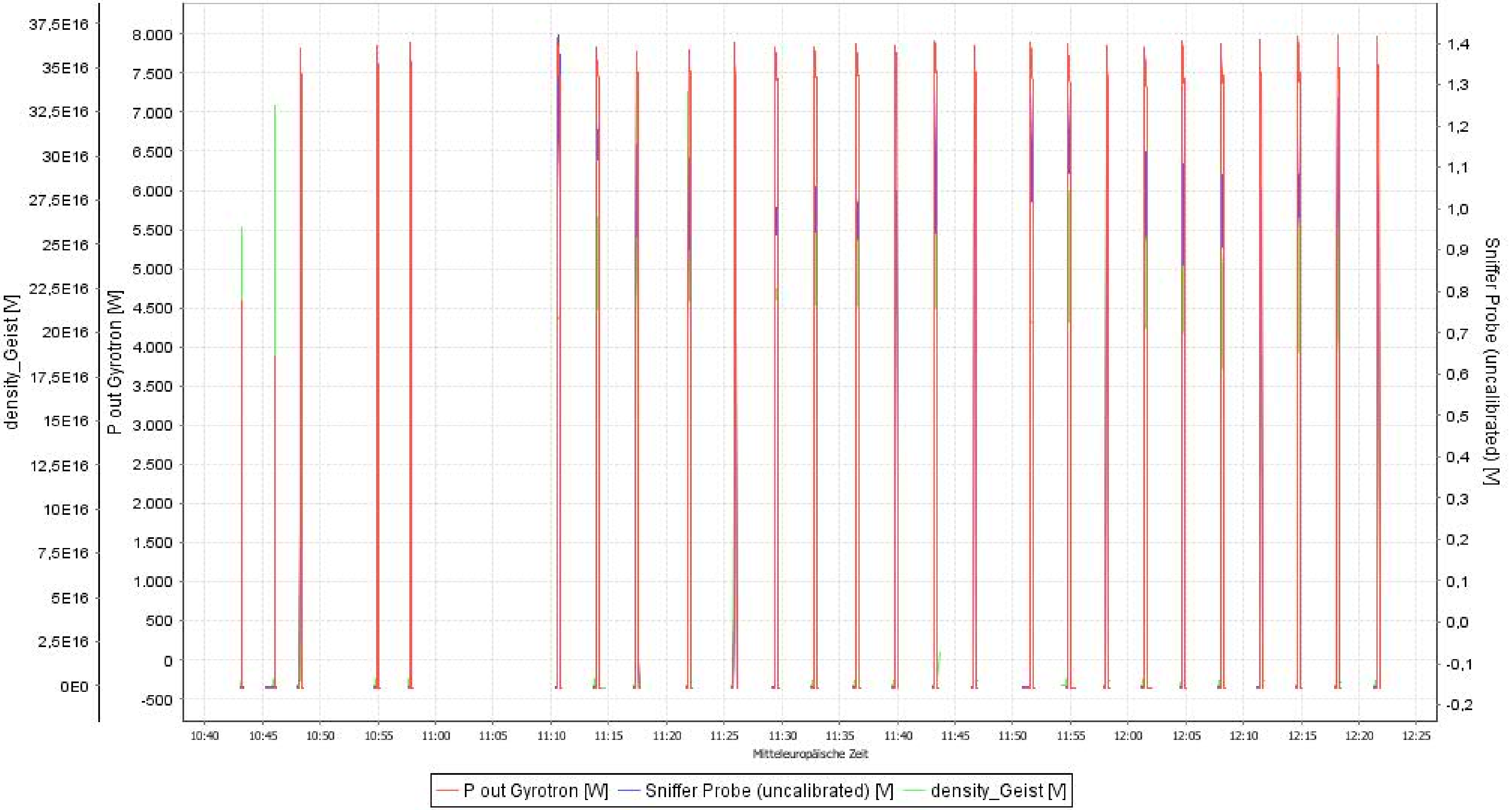
- He discharges with 2.45 GHz and 2kW at 0.087 T cw (1 h) Increases wall temperature to 80-90 °c

- repetitive 15s discharges in He every 200 s with 28 GHz 10 kW at 0.5 T for typical 5 days

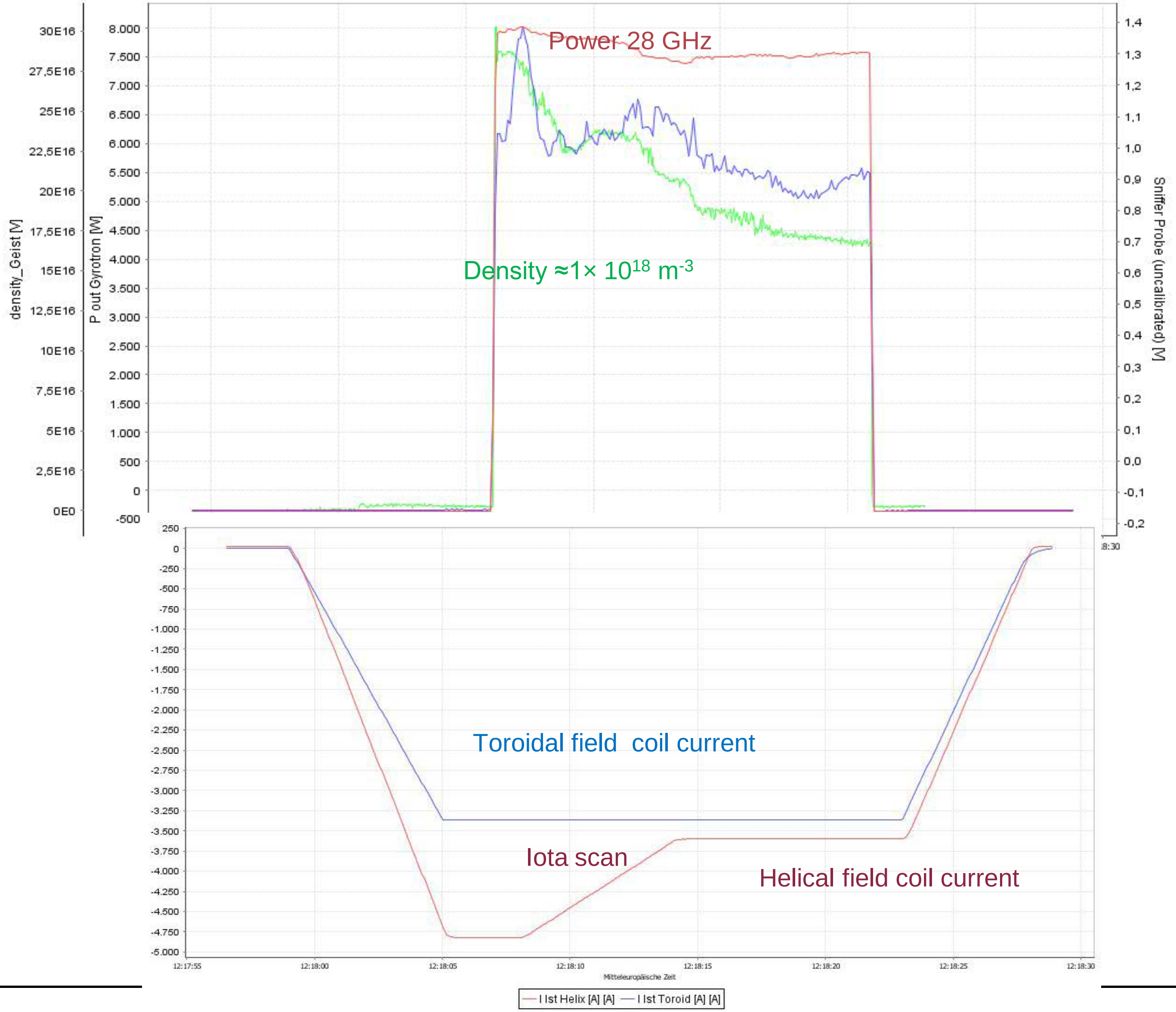
2. during an experimental campaign

- ECRH discharges improve plasma performance day by day.
- Impurity radiation is reduced more and more.

Series of Cleaning Discharges in He



28 GHz ECRH Cleaning Discharge with iota scan



Power 28 GHz

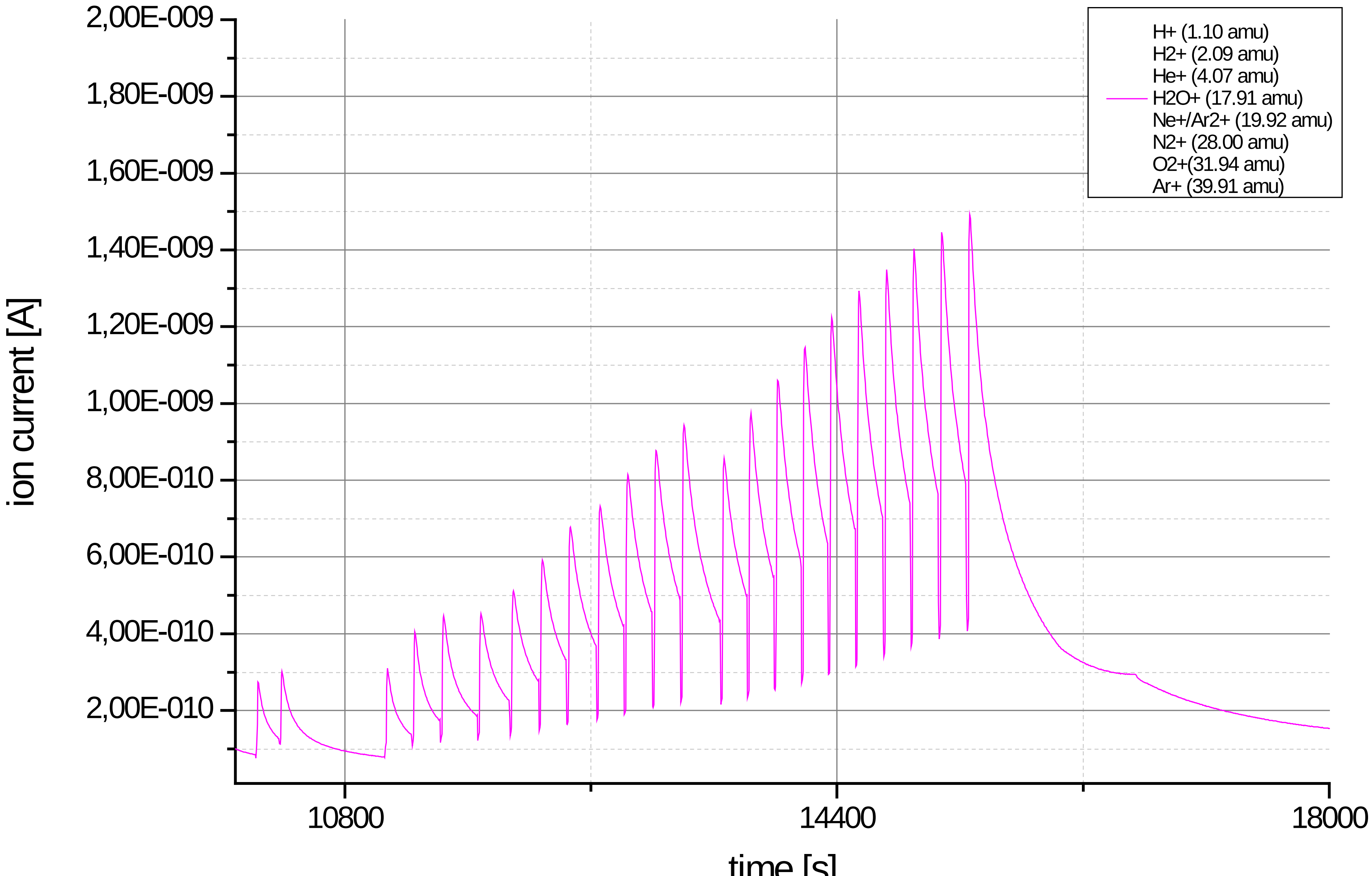
Density ≈1× 10^{18} m^{-3}

Toroidal field coil current

Iota scan

Helical field coil current

H_2O Release 4.11.11



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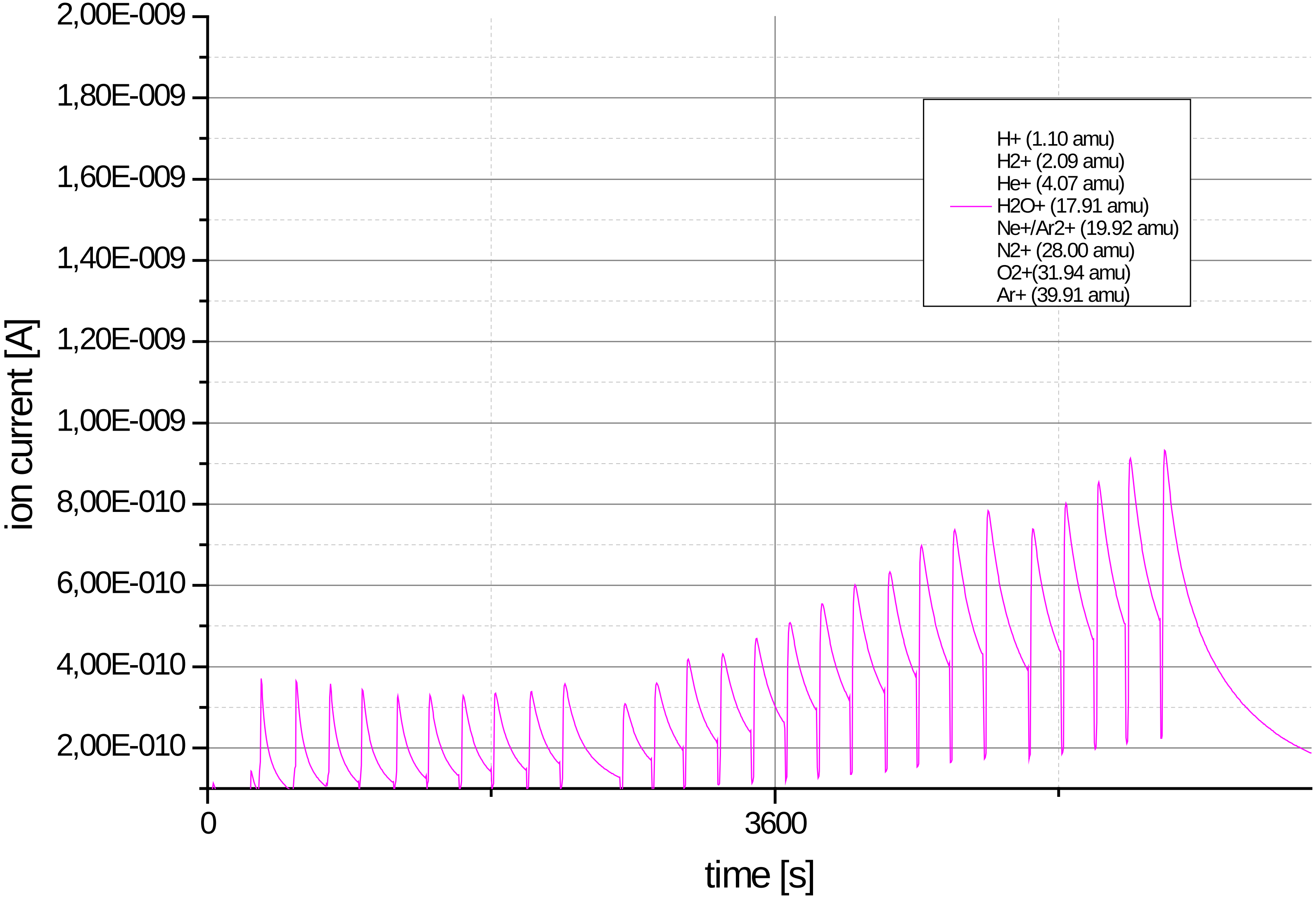
H_2O Release 7.11.11



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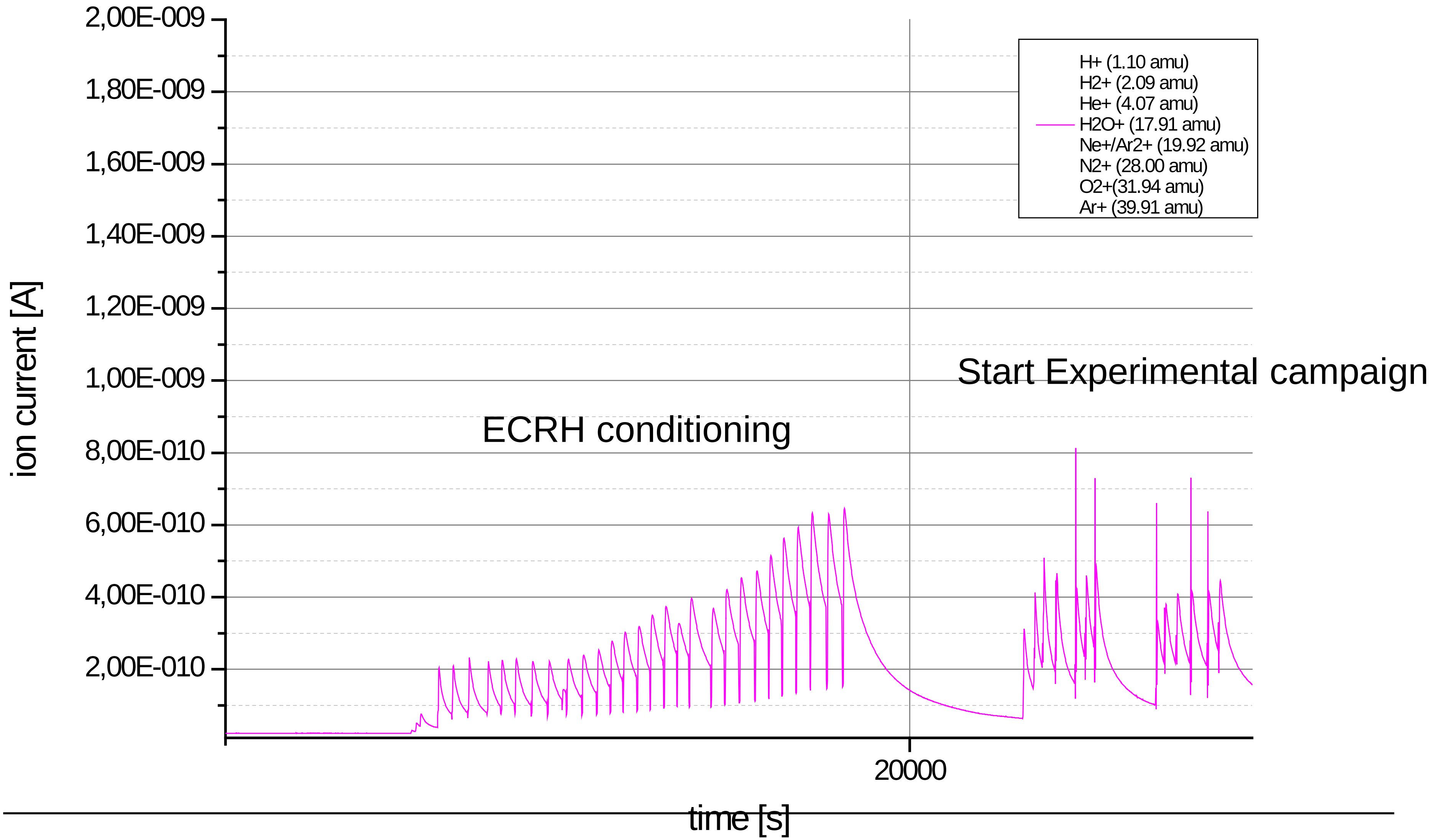
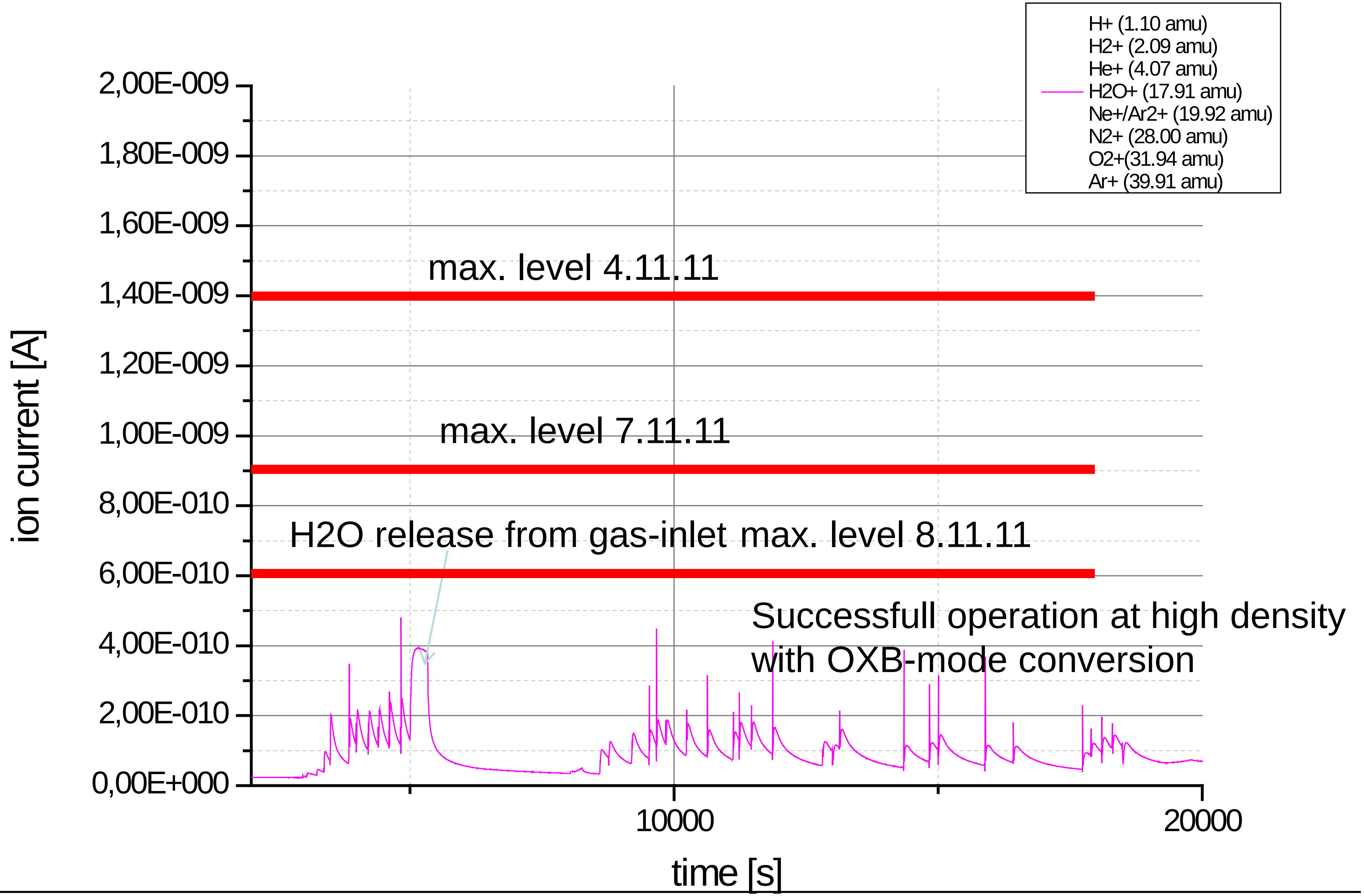
H_2O Release 8.11.11



08 11 11.opj

H_2O Release 9.11.11
Start of Experimental Campaign



max. level 4.11.11

max. level 7.11.11

H2O release from gas-inlet

max. level 8.11.11

Successfull operation at high density with OXB-mode conversion

Strategy for W7-X

1)Evaluate different wall conditioning methods in Stellarators.

1.1) at WEGA

- ICW (3kW 3-20 MHz prepared by Mr. Birus)
- GD (Mr. Aßmus)
- ECRH (28 GHz , 2.45 GHz)
- 2.45 GHz non-resonant

1.2) at LHD

- Experimental proposal was accepted (next slide).

2) Develop a ECRH wall conditioning scenario for W7-X.

Proposed Experiments for LHD: Steady-State and PWL theme group

- Running a long discharge (100-1000s) with 50-200kW cw ECRH in Helium (156 GHz, 77GHz) at low density 1-5 10$^{\wedge 18}$ m$^{\wedge -3}$

- A series of medium power discharges with 1 MW ECRH in Helium for 1-10 s at 1-2 10$^{\wedge 19}$ m$^{\wedge -3}$ with a duty cycle of about 1-10.

- ~~Combination of resonant ECRH (156 GHz, 77GHz) with 2.45 GHz at high field. Our experience from WEGA experiments show that with the help of resonant electron heating the 2.45 GHz can be coupled efficiently. The polarization of the 2.45 GHz should be parallel to the magnetic field (O-wave).~~

- During the cleaning discharge the strike points could be swept slowly by a variation edge iota (coil currents) or plasma position (vertical field) in order to clean a broader surface.

- Comparison with rf-conditioning at ion cyclotron frequency.