Selection of ECRH-Proposals for OP2
(with regard to advanced use of ECRH)

Torsten Stange on behalf of the W7-X ECRH team

1. Overview (1/2)

Commissioning proposals (not necessarily during commissioning phase):

- Optimization of new O2-multipath scenario beyond cutoff density $1.2 \cdot 10^{20}$ m^{-3} (during density gas feedback)
- Optimization of X3-multipath scenario via O2-reflector tiles at $7 \cdot 10^{19}$ m^{-3} (during density gas feedback)
- Optimization of X3-multipath scenario via W-graphite tiles at > 10^{20} m^{-3} (during density gas feedback)
- Commissioning of 175 GHz blibs for CTS-diagnostic
- Commissioning of CTS-radiometer at 210 GHz and 70 GHz
- Commissioning of sniffer diagnostic
- ….

1. Overview (2/2)

Physics proposals:

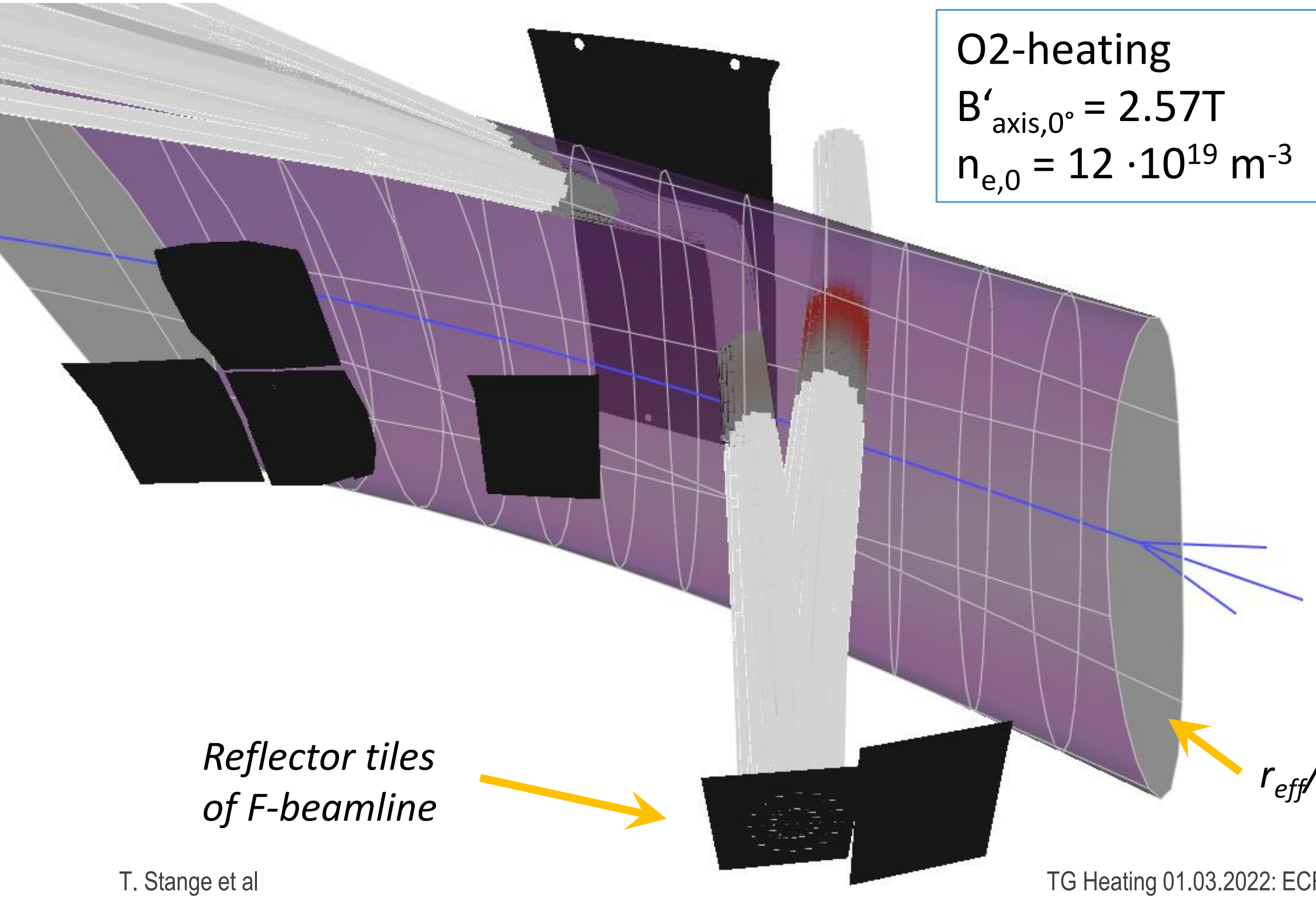
- Performance of high density gas fueled O2 discharges in dependence on the magnetic field
- Probing the optimal power deposition density to overcome the T_i-clamping level
- High performance plasmas by OXB-heating during superdense peaked density profiles sustained by NBI-fueling
- Overtake of peaked high density NBI-plasmas by O2-heating (beyond X2-cutoff) or X3-heating at 1.75 T
- Performance of high n_e-plasmas with freely developing BS current vs zero-current plasmas by ECCD-compensation
- Compensation of BS current and increase of central magnetic shear in high performance discharges by ECCD
- General counteracting of bootstrap current for safety reasons and discovery of unexpected transport barriers
- Mimic BS current in a high density O2-scenario
- Performance of the different X3-heating scenarios at medium and high density (partly piggyback on 1.75T proposals and already part of X3-commission proposal => see also talk 01.02.2022)
- Startup physics proposals => collected/organized by Dmitry Moseev
- Variety of stray radiation proposals => collected/organized by Jakob Brunner
- Variety of parametric decay proposals => by Riccardo Ragona

⇒ *Many of these proposals are still in the "conceptional" phase … please contact me (torsten.stange@ipp.mpg.de) if similar proposals are already planned in other TGs or if you want to be included in the further proposal planning*

2. Commissiong proposals: O2-reflector tiles

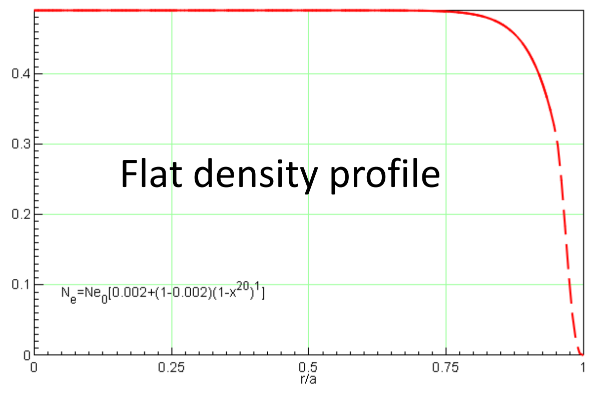
- O2-heating scenario was redesigned for OP2 to reduce stray radiation by about 50% (higher incidence angles with regard to B + beampaths slightly off-axis to allow use of polarization gratings)

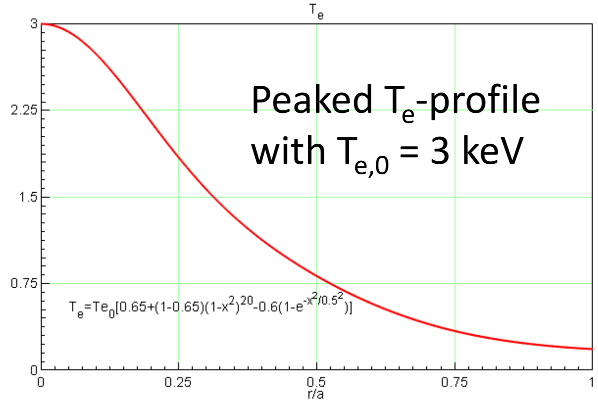
$\Rightarrow$ *Commissioning proposals for O2-scenario and X3-scenario*



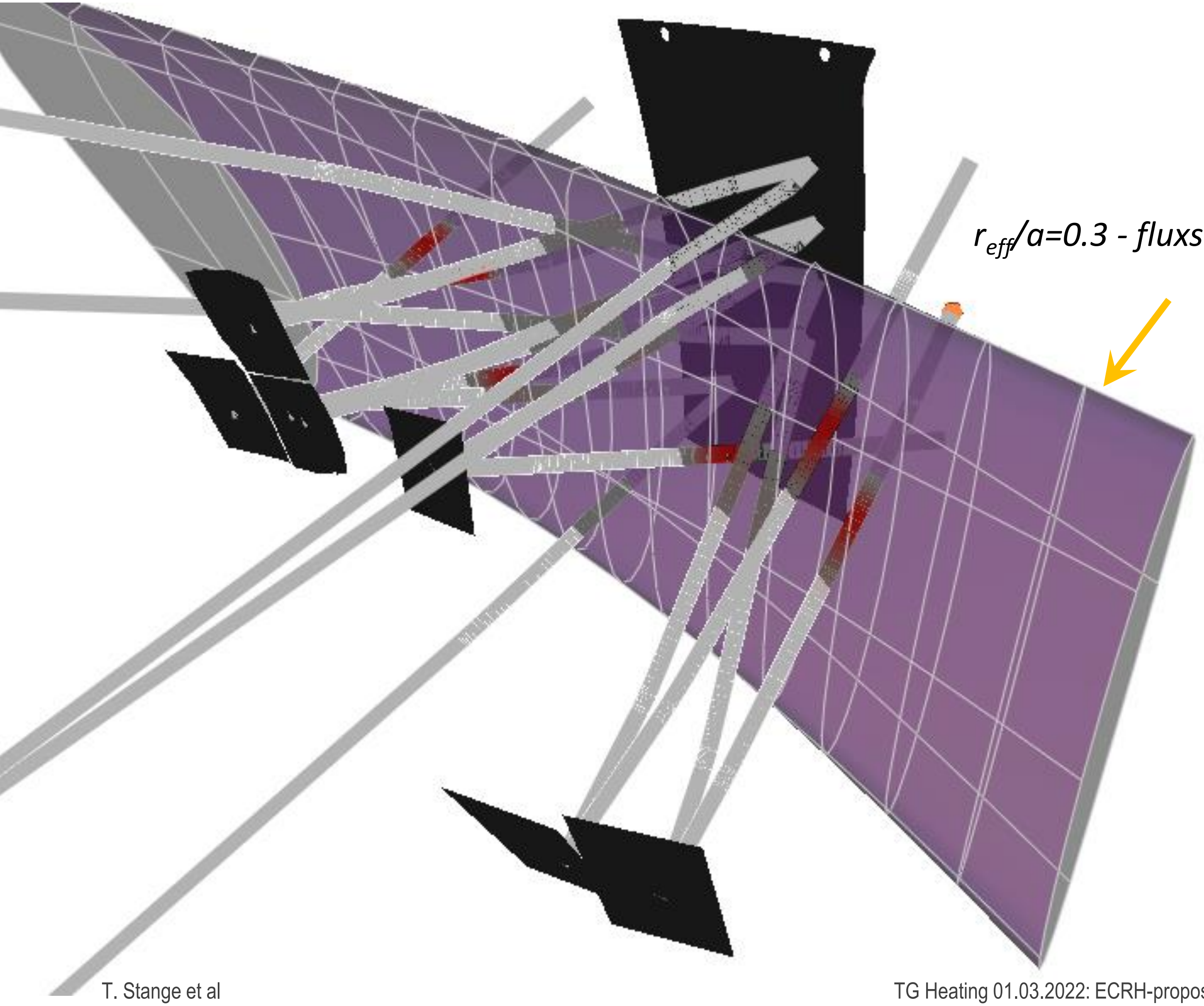
O2-heating
$B'_{axis,0°}$ = 2.57T
$n_{e,0}$ = 12 $\cdot 10^{19}$ m^{-3}

Input power = 5.5MW





2. Commissiong proposals: O2-reflector tiles



- Power modulation of each gyrotron separately to identify badly absorbed beams
- slight change of polarization, slight change of beam position
- demonstration of optimized polarization gratings (only small increase of stray radiation with aproaching cutoff)

⇒ Try to fit an optimization procedure of all beams into a 20s-programm

Conditions:

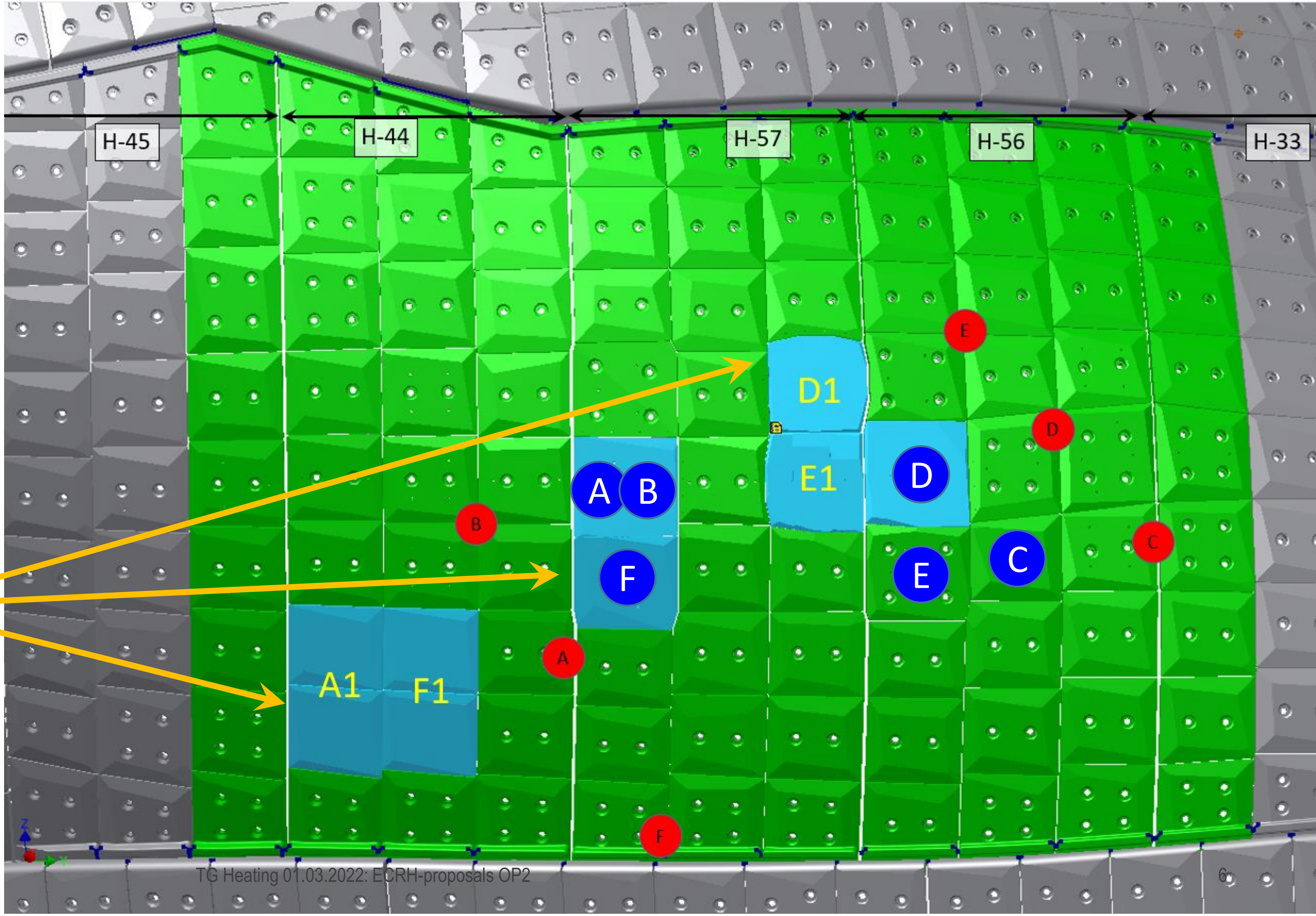
- Divertor gas feedback
- about 2 x 6 shots for O2
- about 5 shots for X3 via reflector tiles
- about 10 shots for X3 via W-coated tiles

2. Commissiong proposals: X3 via W-coated tiles

- broad area of heat shield opposite to ECRH-Launchers is W-coated in OP2 (green)
- same low absorption of direct ECRH-beam compared to dedicated reflector-tiles

⇒ possibility to use W-coated graphite tiles for several seconds as non-optimized reflector during X3 (take care of arcing)

TZM-reflector tile dedicated to O2 (also W-coated)



Red dots: *perpendicular incidence during X2*

Blue dots: *possible reflectors for high density X3*

3. Physics proposals: high density O2-operation (1/2)

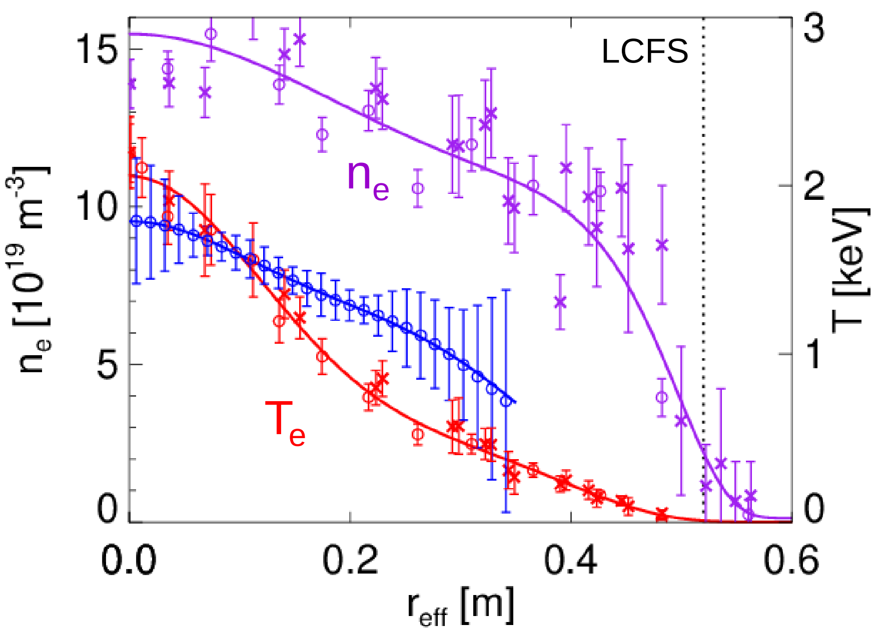
Title: Performance of high density gas fueled O2 discharges in dependance on the magnetic field (and the influence of trapped and passing particles)

Background:

- highly fueled O2-heated discharges beyond the X2-cutoff density showed slighty peaked density profiles in OP1.2b and probably therefore also a good plasma performance
- One reason seems to be the broader O2-power deposition

⇒ slight off axis deposition was allowed for new O2-multipath scenario which reduces the stray radiation by a factor 2

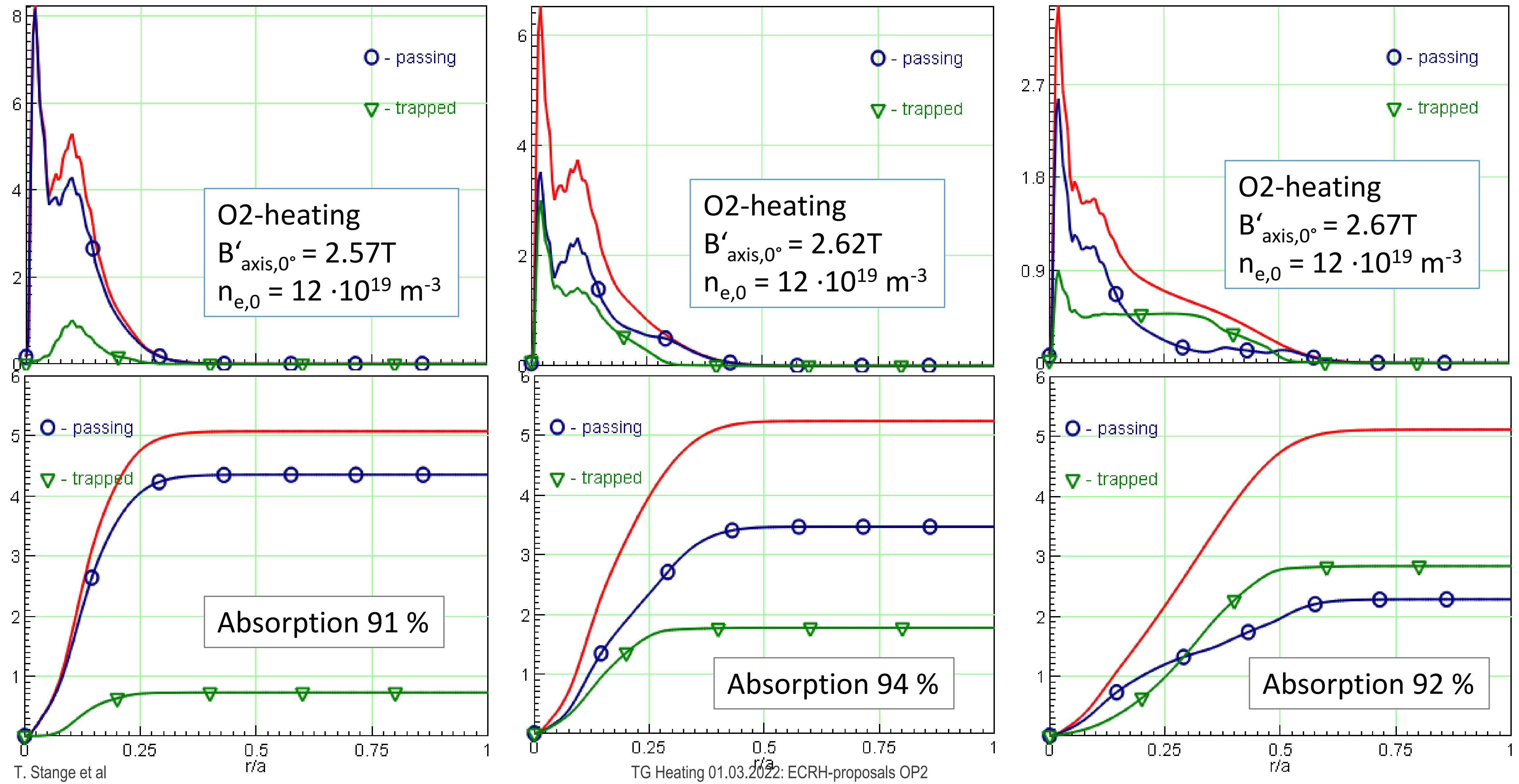
- the O2-deposition can be varied by a change of B including a variation of the content of passing and trapped particles



Proposal:

- probe the optimal magnetic field for maximum plasma performance
- centrally depositing beams are used only at the final density level to do not allow an early separation of T_e and T_i
- transport probed by modulation of different ECRH beams (success expected for centrally depositing beams)
- Standard ECE and CTS-radiometer is used to identify differences for trapped and passing particles (even though no influence is expected due to the high collisionality)

3. Physics proposals: high density O2-operation (2/2)



3. Physics proposals: Optimal power deposition density

Title: Probing the optimal power deposition density to overcome the T_i-clamping level

Background:

- NTSS calculations show no change of the achieved ion temperature if the ECRH power deposition is broadened up to a minor radius of r/a < 0.3

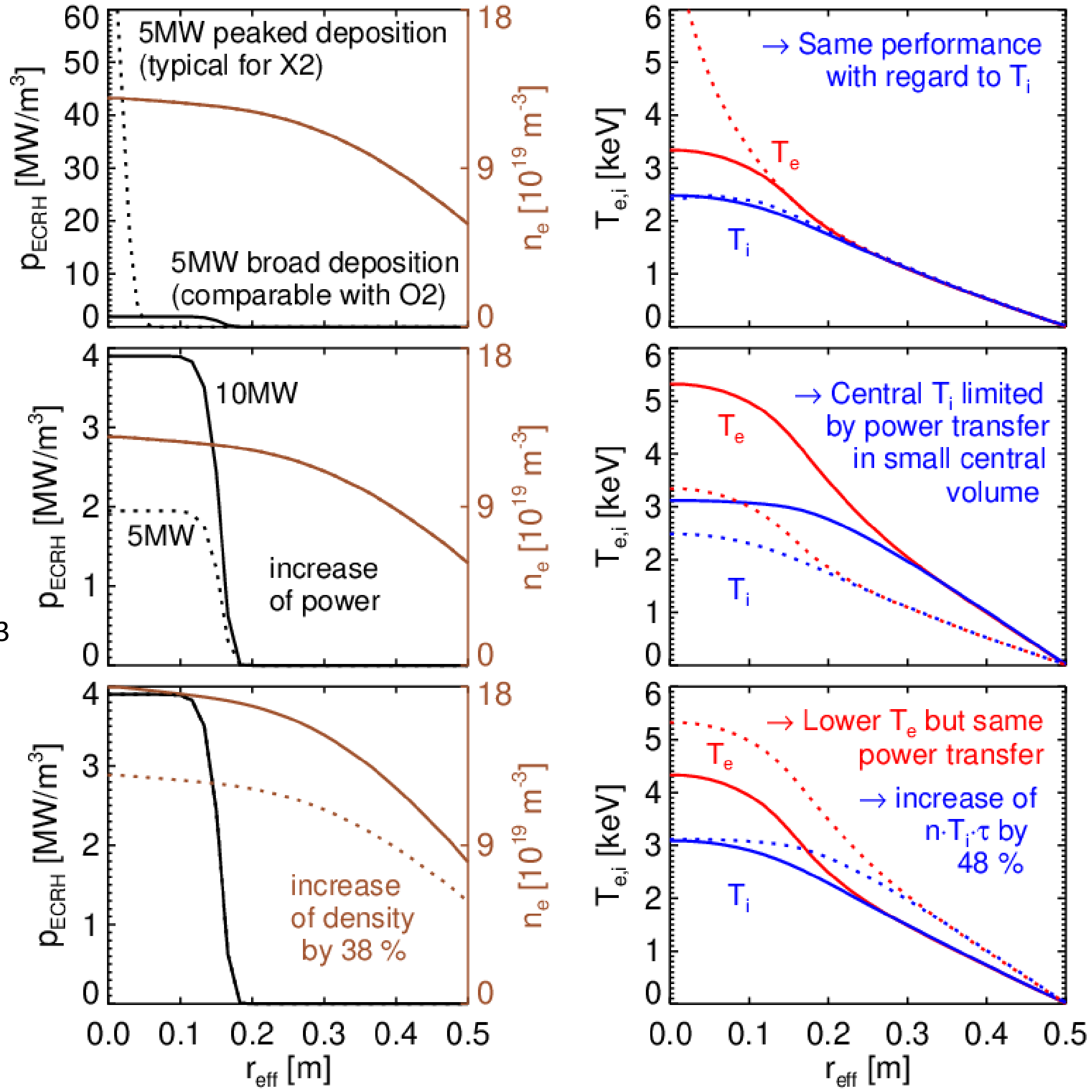
⇒ Even though high T_e are achieved with central power deposition, the interaction volume for energy transfer from the electrons to the ions is limited

Proposal:

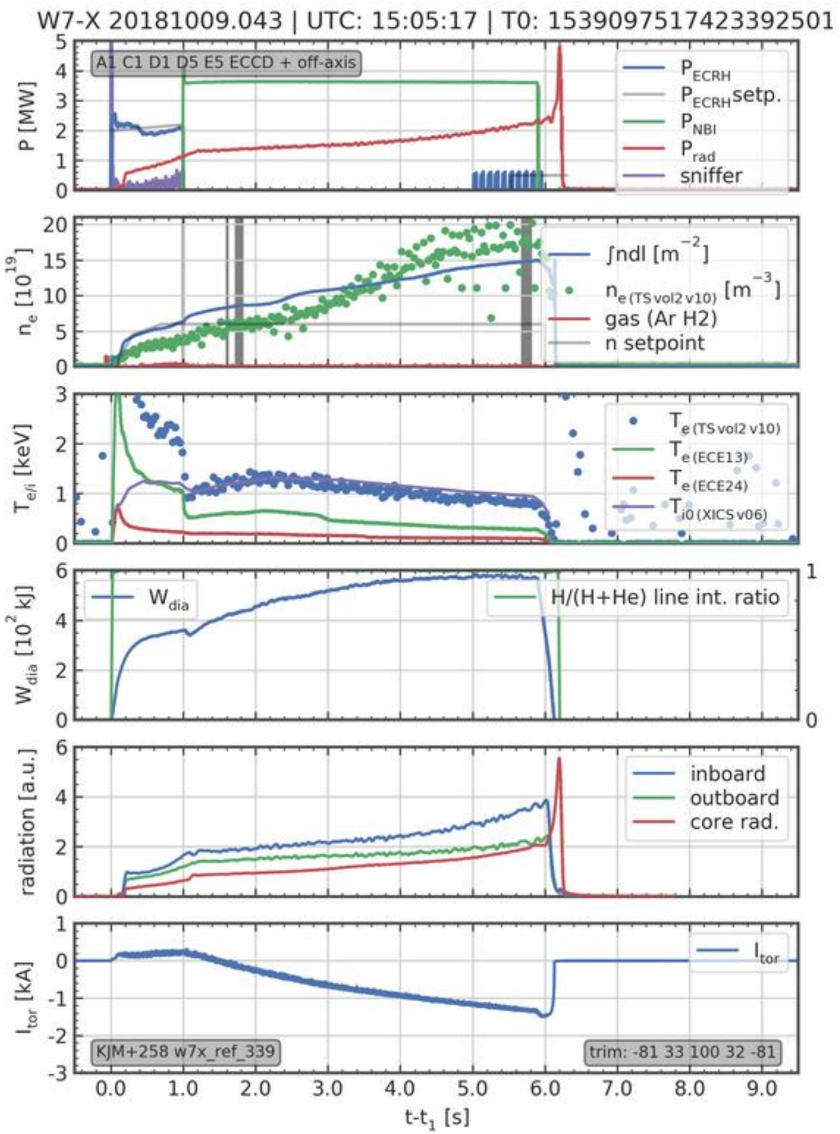
- Start of discharge with broad power deposition < 1MW/m^3 (eventually without power deposition around plasma axis)
- increasing smoothly the overall power and power deposition density up to 2 MW/m^3 and beyond

⇒ probe an eventual critical power deposition density

- If successful this kind of scenario should be repeated for different target density levels



3. Physics proposals: OXB-studies (1/2)



<u>Title:</u> High performance plasmas by OXB-heating during superdense peaked density profiles sustained by NBI-fueling (+ eventually pellet fueling)

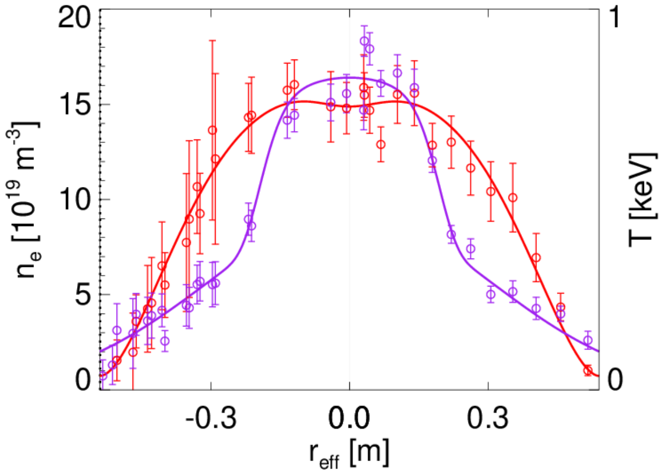
<u>Background:</u>

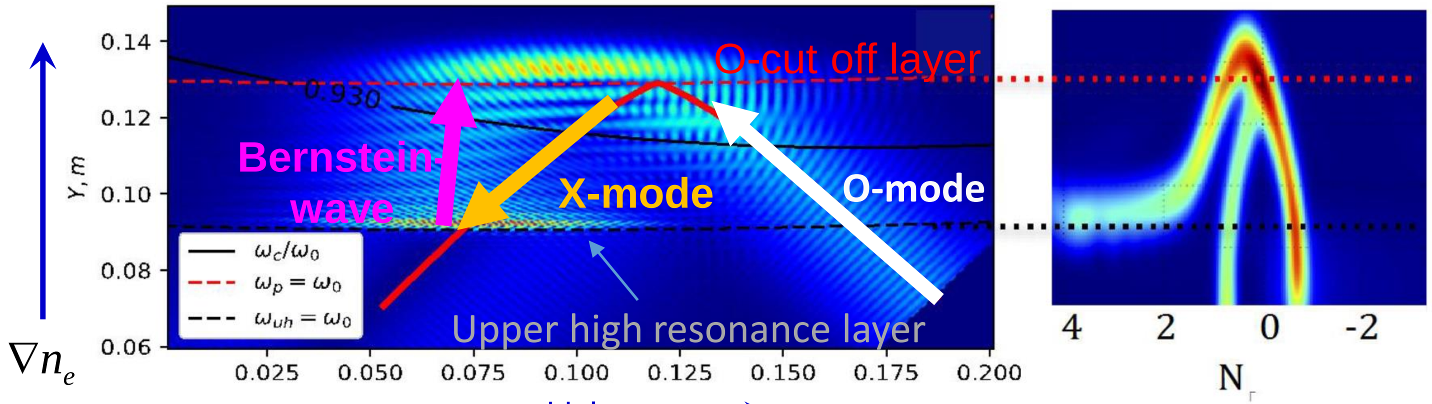
- possibility to achieve densities beyond 2×10^{20} m^{-3} with steep density profiles

⇒ Conditions for electron Bernstein wave heating via OXB-conversion

- First tries in OP1.2b but too low density
- 4 NBI-sources available in OP2

⇒ 140 GHz cutoff @ $2.4 \cdot 10^{20}$ m^{-3} seems to be no problem anymore





[CUWA-calc by Aleynikov]

3. Physics proposals: OXB-studies (2/2)

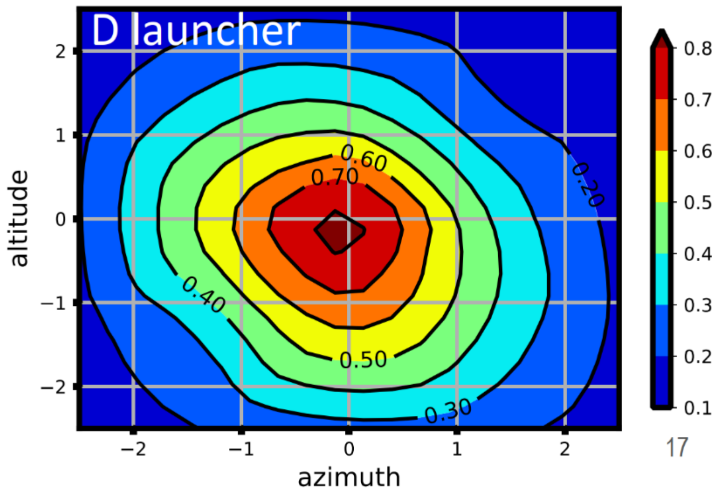
Conditions: Search for reproducible NBI-scenario with almost stable density > $2.4 \cdot 10^{20}$ m^{-3}

- First, pulsed experiments to investigate coupling of single ECRH beams and response of density

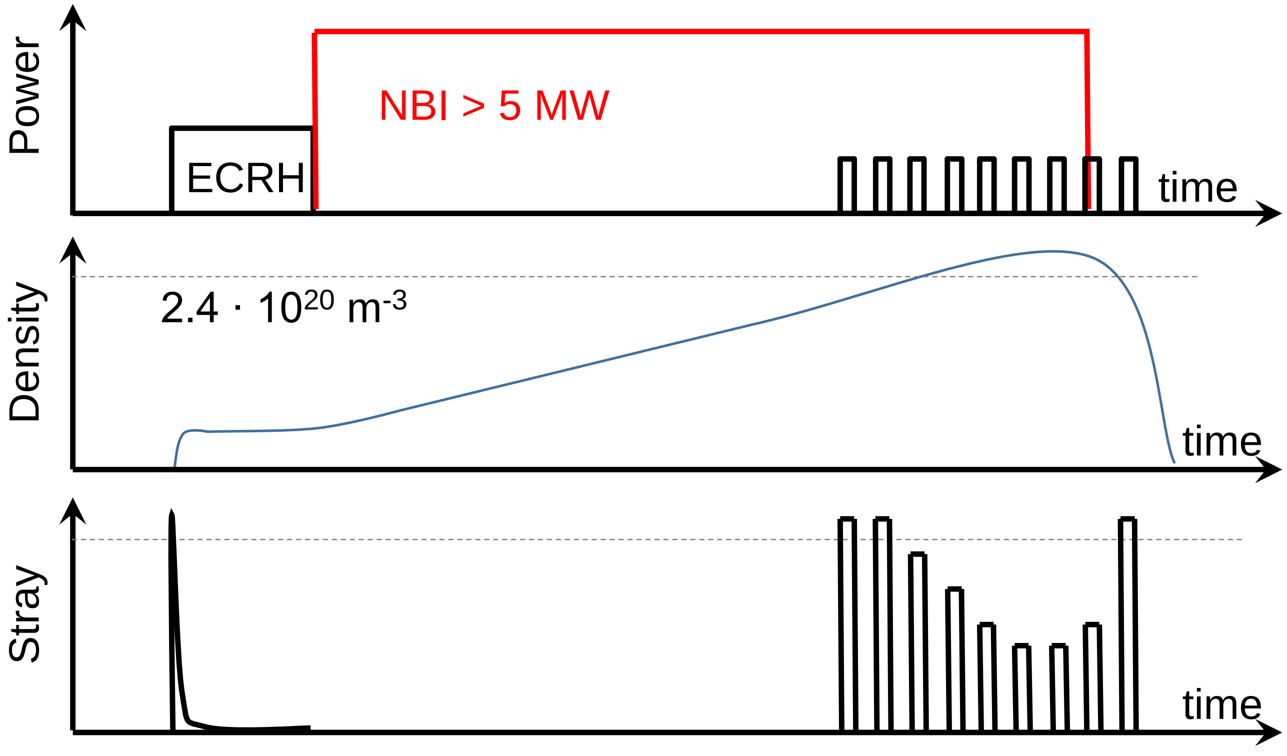
$\Rightarrow$ eventually tests with additional pellet fueling if density pump out is too heavy

- 2D angle scan, because angle window quite small

Efficiency of OX conversion for beam aiming angles around the optimal ray



Proponents:
P. Aleynikov
N. Marushchenko
T. Stange
S. Lazerson



- Increasing pulse length and power to increase T_e and T_i

$\Rightarrow$ T_i-clamping will be no issue

- About half of the beams can achieve OX-window => up to 4 MW
- Envisaged scenario comparable to superdense core scenario at LHD

3. Physics proposals: Overtake of NBI-plasmas by O2/X3

Title: Overtake of peaked high density NBI-plasmas at around $1.5 \cdot 10^{20} m^{-3}$ with O2-heating (beyond X2-cutoff)
Overtake of peaked high density NBI-plasmas at around $1.2 \cdot 10^{20} m^{-3}$ with X3-heating at 1.75 T
(+ eventually additional pellet fueling for both scenarios)

Background:

- "naturally" peaked density profiles of NBI-plasmas give a good starter for injecting high power ECRH combined with immediate good coupling between electrons and ions
- The intrinsically broad power deposition of O2 and X3 is the key issue for this experiments

Proposal:

- Immediate switch-on or stepwise increase of ECRH-power will be tested (use of 2 NBI-sources)
- goal is to increase T_e and T_i in the center with peaked density profile to overcome T_i-clamping-level with the available ECRH power
- eventually tests with additional pellet fueling if density pump out is too heavy
- gas fueling should be avoided as much as possible to limit the edge density and to allow higher edge temperatures
- Dependent on results of O2-optimization repeat with different B

3. Physics proposals: Compensation of BS at high density

Title: Performance of plasmas with freely developing bootstrap (BS) current vs zero-current plasmas by ECCD-compensation at high densities

Background:

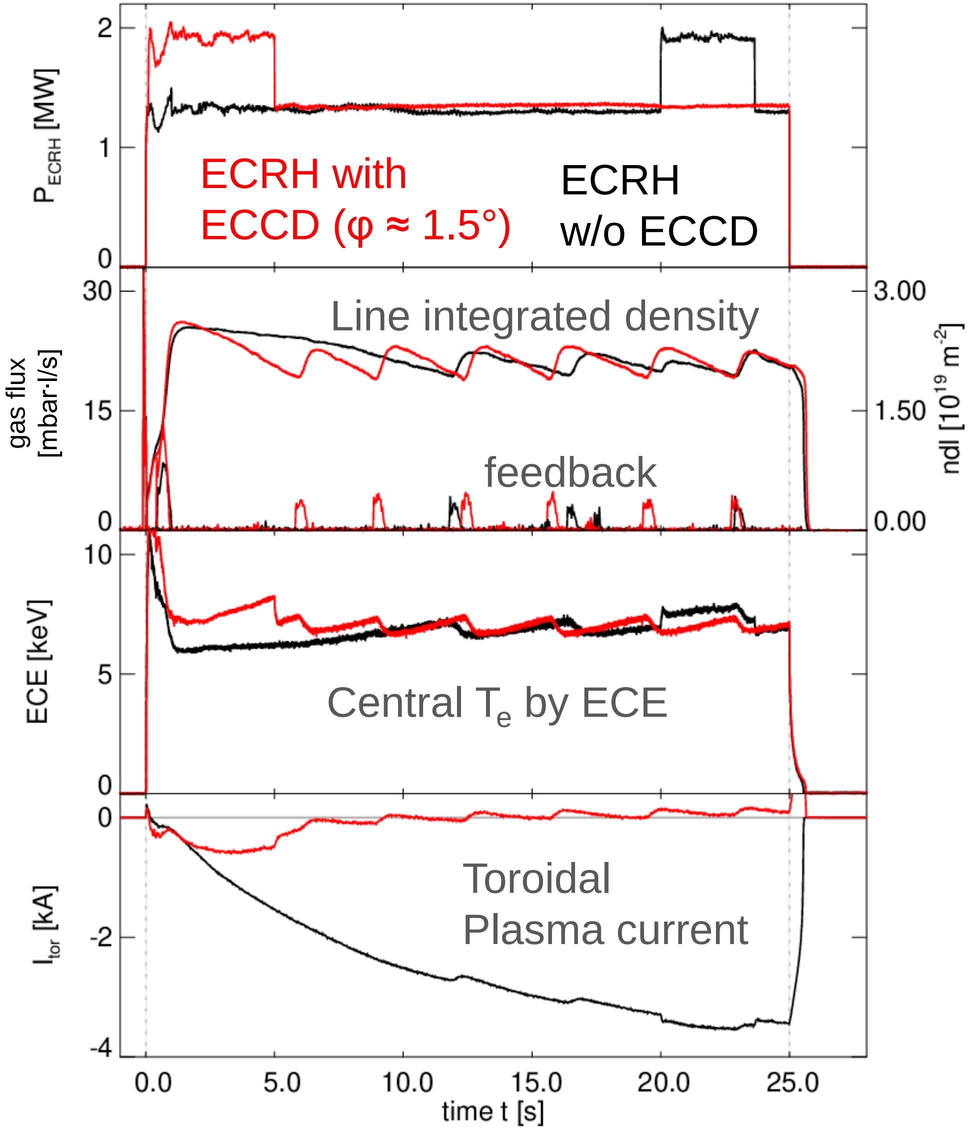
- ECCD-compensation up to 20kA is possible even at high densities

⇒ In addition magnetic shear can be changed (this important tool was almost not used in OP1.2!)

- proposal includes the demonstration of the compensation of the bootstrap-current by ECCD to keep strike lines constant
- An additional goal is to quantitatively compare the performance of a zero-current plasma vs a plasma with freely developing bootstrap current

Proposal:

- deposition radius must be identical as well as the density feedback
- strike line position should be kept as constant as possible by using the sweep coils or changing the main coils currents in the reference discharge



3. Physics proposals: ECCD for magnetic shear control

<u>Title:</u> Compensation of BS current and increase of central magnetic shear in high performance discharges by ECCD

<u>Background:</u>

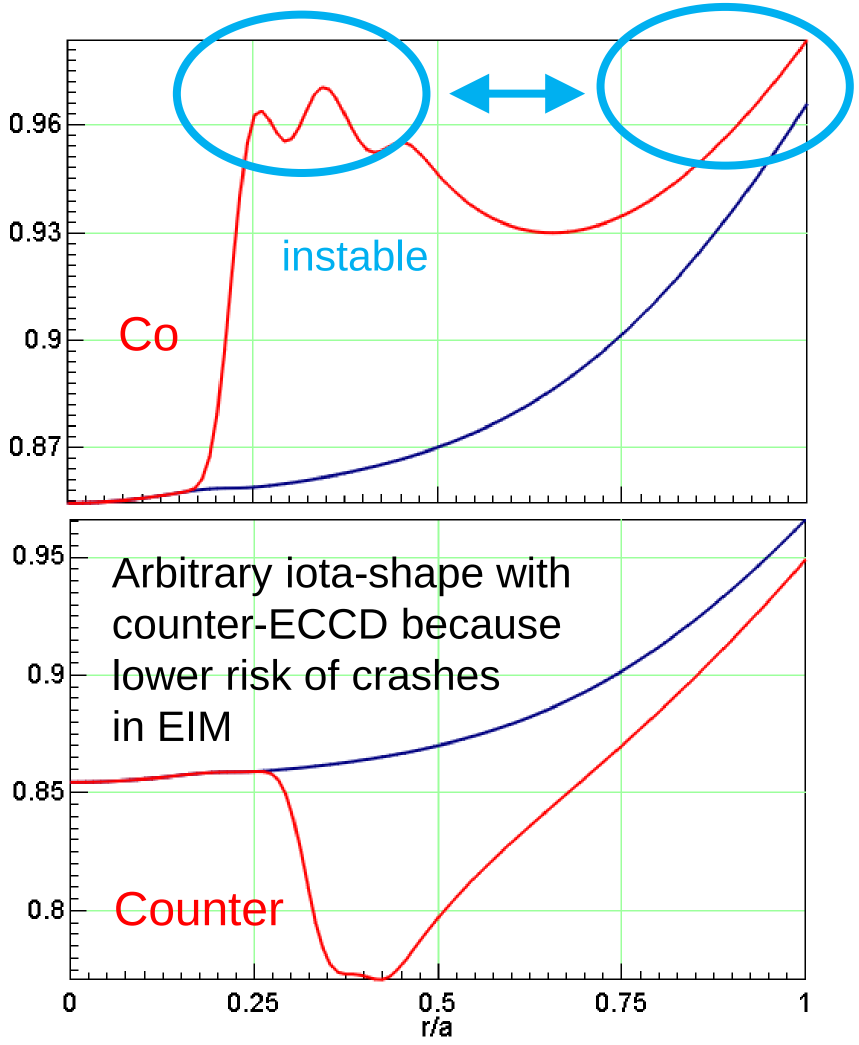
- improved confinement phase in high performance pellet discharges is unstable (probably not only due to the limited pellets up to now)
- Internal currents (BS + central shielding currents) due to the strongly peaked density profile can play a role

<u>Proposal:</u>

- Using of moderate and broadly distributed Counter-ECCD to stabilize the central plasma by increasing the magnetic shear
  + compensation of the overall BS-current
  + compensation of deposition shift due
  to shafranov shift + central B-reduction
- However, Co-ECCD is also worth to try
  (at least to demonstrate the inverse effect).

⇒ ECCD will be increased smoothly to reduce effect of shielding currents
(shielding current of Counter-ECCD can lead to crossing of iota = 1, too)

Proponents:
H. Laqua
T. Stange



3. Physics proposals: General use of ECCD for BS-comp.

<u>Title:</u> General counteracting of bootstrap current for safety reasons and discovery of unexpected transport barriers

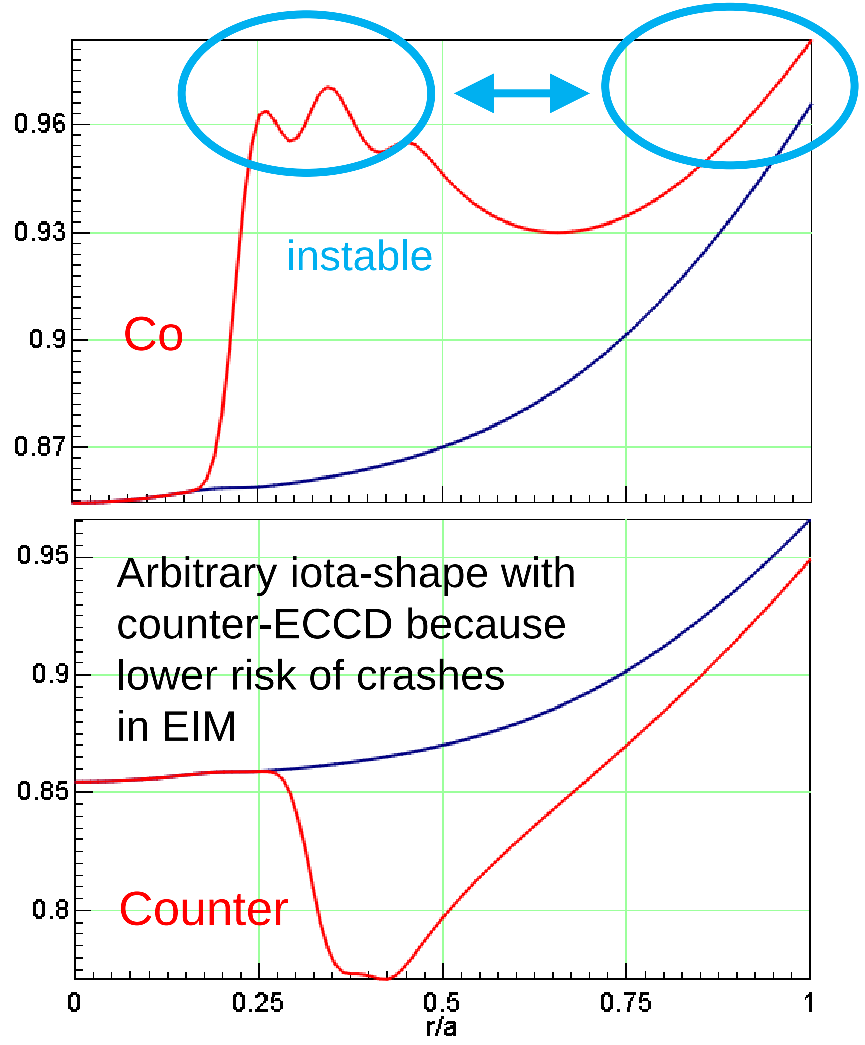
<u>Background:</u>

- bootstrap current usually increases the edge iota and changes the strike line position.
- Dependent on the distribution of the currents within the plasma the magnetic shear is also changed locally during the evolution of the BS-current.

<u>Proposal:</u>

- For safety reasons, moderate ECCD can be used in general to reduce or compensate the BS-current (e.g. low iota or standard config).
- this strategy can maybe lead to the discovery of unexpected confinement behaviour like "triggering" of transport barriers due to the change of the magnetic shear by additional current layers

$\Rightarrow$ Most of the interesting phenomena are discovered by trying something



3. Physics proposals: Mimic BS in high density scenario

Title: Demonstration of a discharge evolution scenario up to maximum densities where the final bootstrap current is mimicked by ECCD at the beginning of the discharge

Background:

- Plasma operation with coil currents having optimal strike line position for maximum bootstrap current can be combined with mimicking BS at the beginning of a discharge by use of ECCD

⇒ Demonstration in OP1.2 at low densities (proposal by Turkin)

Proposal:

- optimum steady state high performance plasma not yet found

BUT: possibility to mimic the BS-current in a high density O2-scenario should be demonstrated. Otherwise, eventual issues with the control systems (or even the physics) are identified to late in OP2

Proponents:
Y. Turkin
C. Beidler
T. Stange