Joint NIFS-IPP International Collaboration on the Comparison of ECRH heated Plasmas and CERC

Felix Warmer

20. January 2017

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

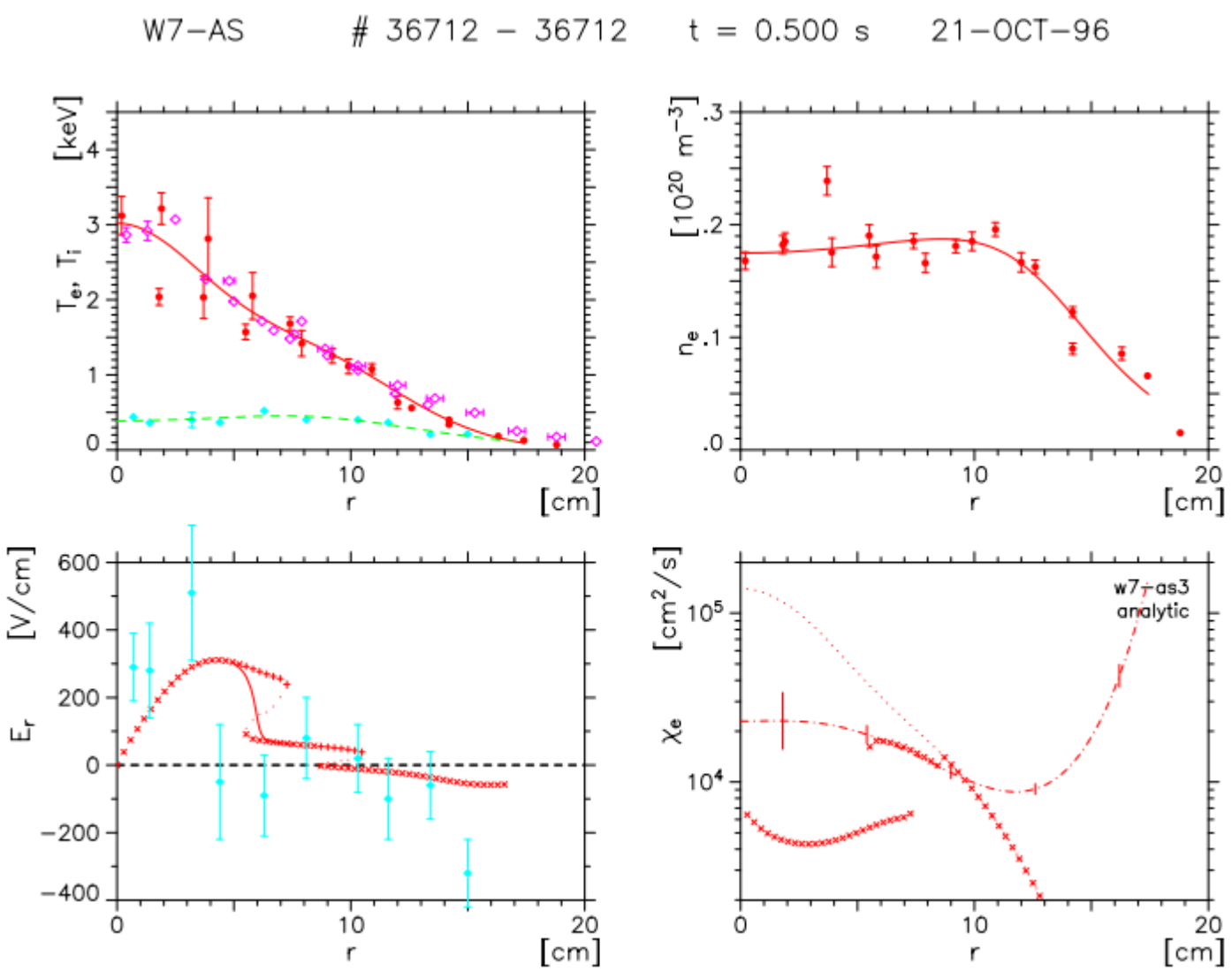
CWGM 2017, Madrid

A. Alonso[1], C.D. Beidler[1], A. Dinklage[1], J. Geiger[1], H. Maaßberg[1], S. Murakami[3], Y. Turkin[1], R.C. Wolf[1], M. Yokoyama[2], R. Seki[2], Y. Suzuki[2], H. Takahashi[2], Y. Yoshimura[2], the W7-X Team, and the LHD Experiment Group

… participants and collaborators welcome

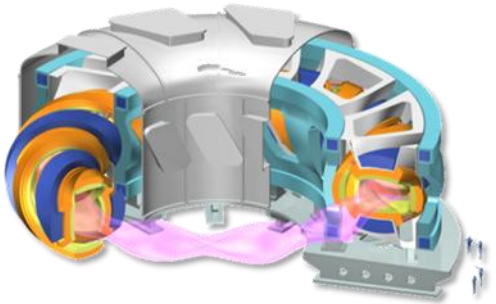
[1]Max Planck Institute for Plasma Physics, Greifswald (Germany)
[2]National Institute for Fusion Science, Toki (Japan)
[3]Kyoto University, Departement of Nuclear Engineering, Kyoto (Japan)

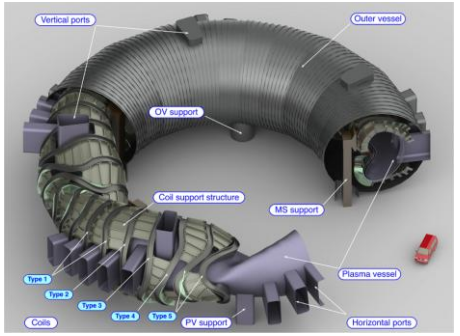
What is core-electron-root-confinement (CERC)?



Motivation

- W7X and LHD are the largest helical magnetic confinement devices in the world
- CERC provides opportunity to investigate and assess specific transport features
  - In particular the impact of the radial electric field
- This is necessary in order to build a strong knowledge foundation to go to the next generation of larger devices with a burning plasma





ECRH heating capability

LHD

- 6 Gyrotrons (3x 77 Ghz (O1), 2x 154, 82.7)
- ~6 MW → 5.4 MW port-through for 1-2s
- ~90% transmission efficiency (waveguide)

- → 5 MW effective heating power (1-2s)

- configuration mostly R_{ax} = 3.60m, 2.7 T

W7-X (OP1.1)

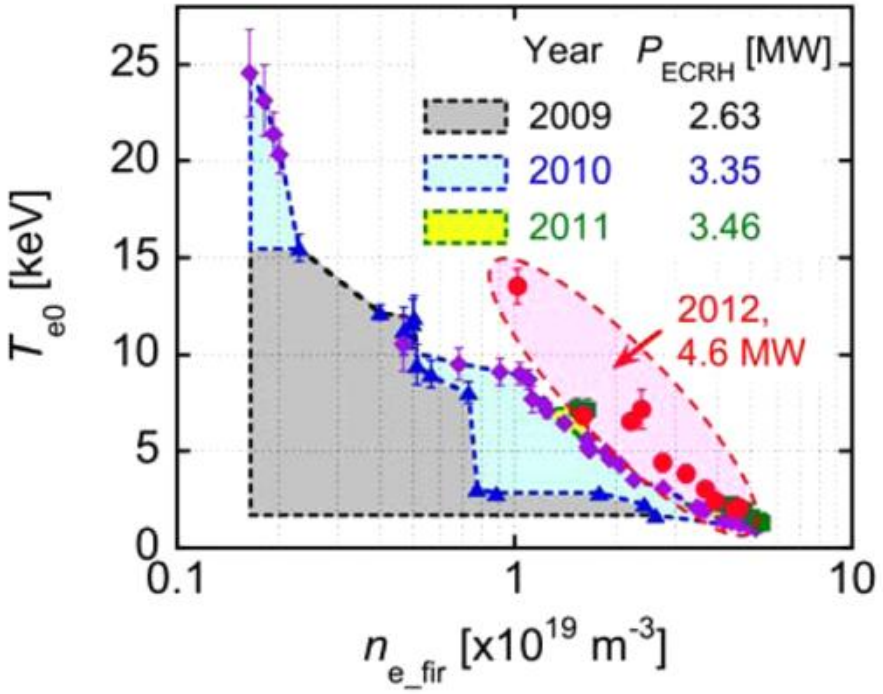
- 6 Gyrotrons (140 Ghz, X2, O2)
- ~6 MW, basically CW (30 min)
- >95% transmission efficiency (quasi-optical)

- → 6 MW effective heating power (limited in OP1.1 by 4 MJ energy limit)

- configuration “J”, index 1, 2.5 T (OP1.1 limiter configuration)

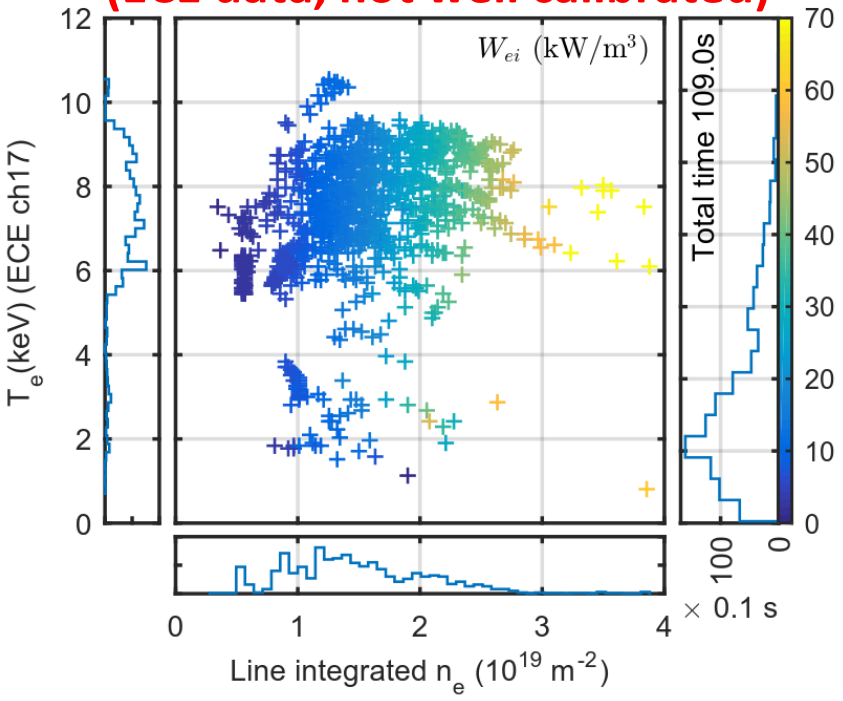
ECRH achievements

H. Takahashi, et al., PoP 21 (2014)



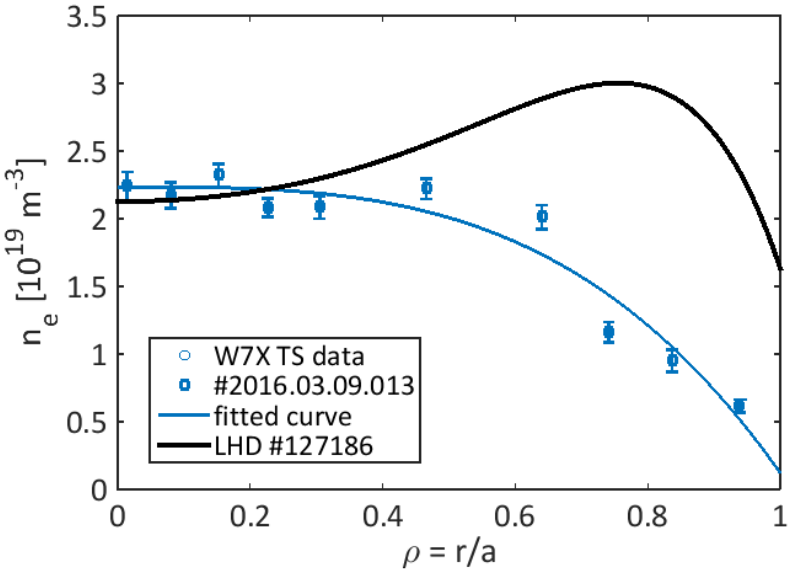
A. Alonso, et al., W7 Meeting

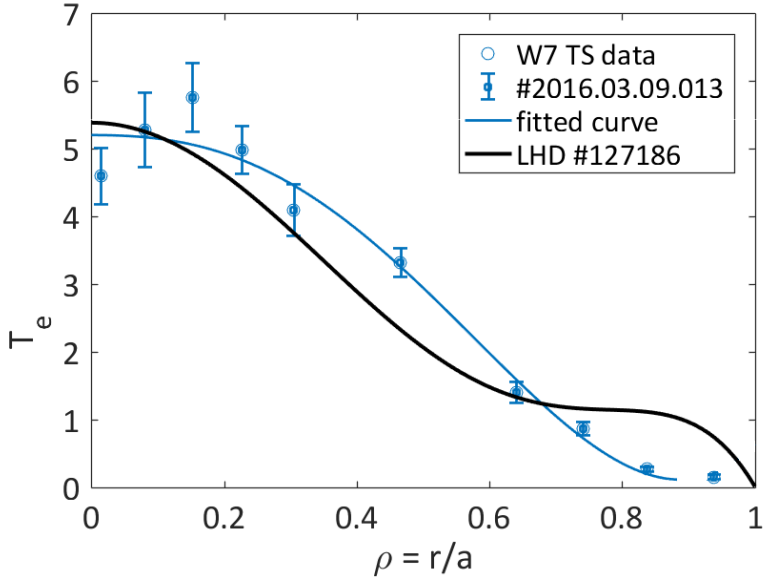
(ECE data, not well calibrated)



- Both achieved > 10 keV at densities about 1*10^{19} m^{-3} .
- LHD: ~ 5 keV @ 2-3*10^{19} m^{-3} ← → W7X: ~ 5 keV @ 2-3*10^{19} m^{-3} (TS data)
- Larger scatter in W7X experimental data (discrepancy ECE—TS)

Profile Comparison (Thomson Scattering)



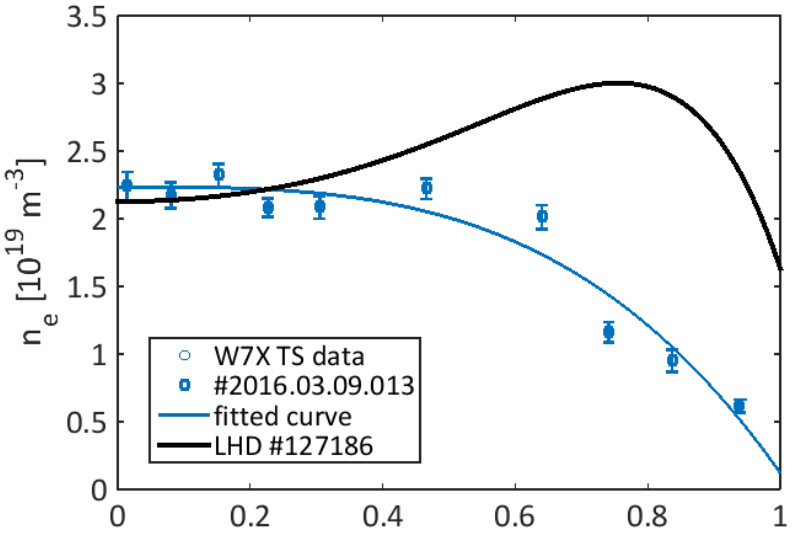


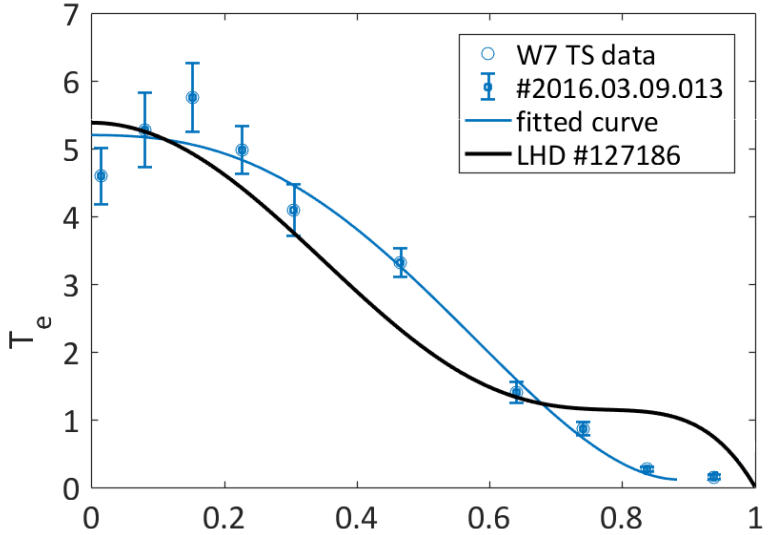
***(W7-X: r/a = 1 represents limiter)**

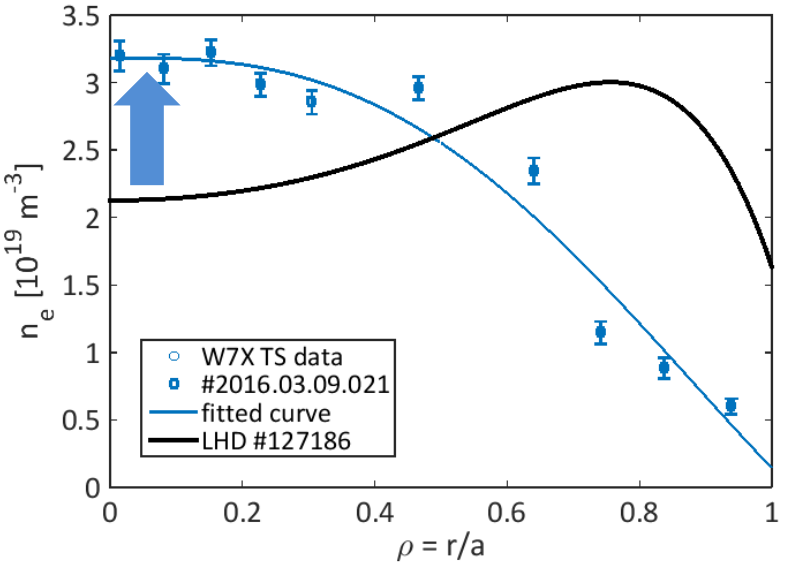
***Effective heating by ECRH: 2 MW**

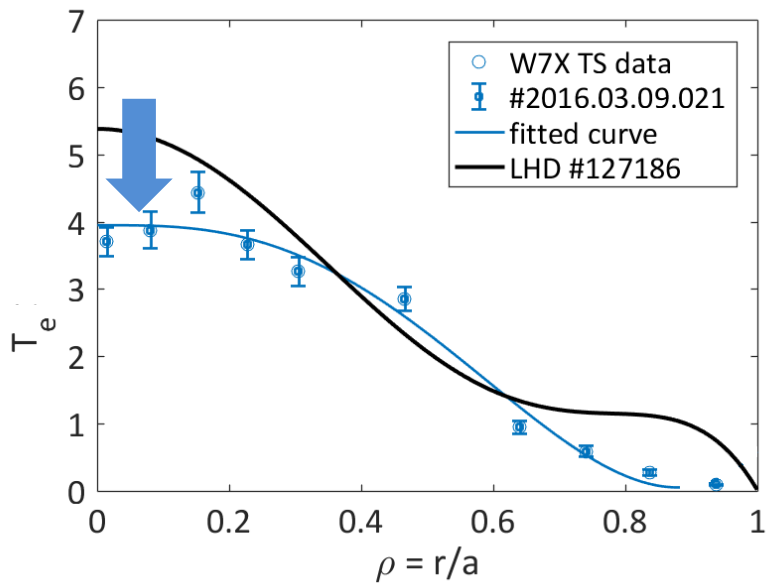
***matched for central density**

Profile Comparison





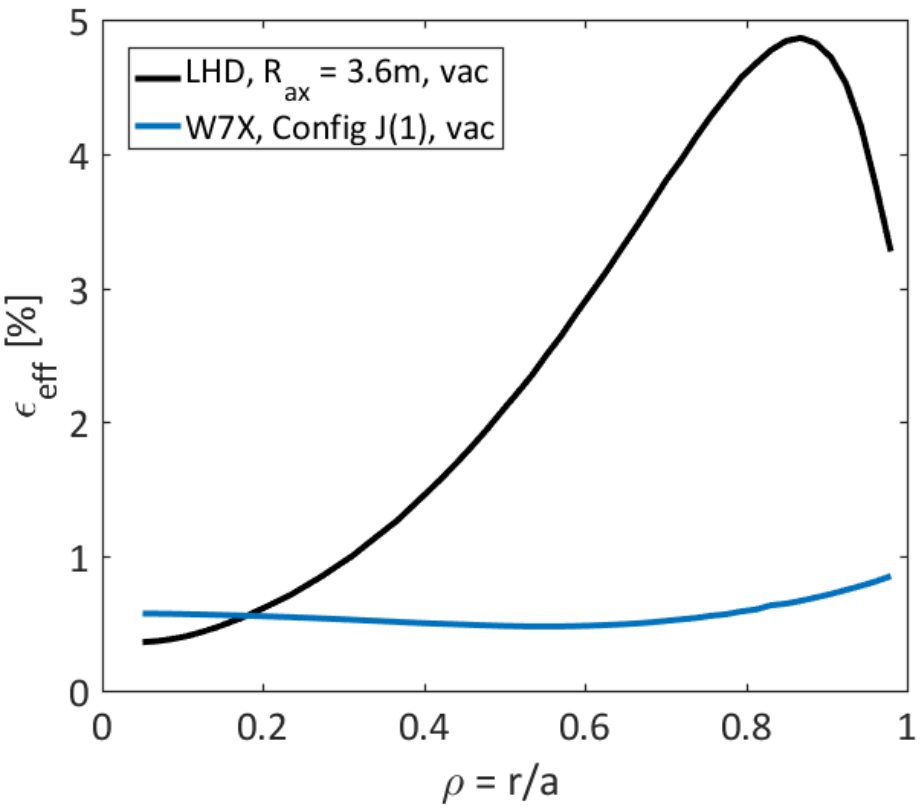




Observations

- Strongly hollow density profiles in LHD
  - Recycling provides stronger central fueling in W7X due to the limiter
- For similar plasma core density → similar core temperature (r/a < 0.3)
- Temperature profiles start to deviate outside plasma centre (r/a > 0.3)
  - W7X temperature goes quickly to zero (r/a = 0.8)
    - (maybe due to strong impurity radiation, Z_{eff}=2-3, and charge-exchange??)
  - LHD temperature stays at > 1 keV towards the plasma edge
    - (although density is much higher 2-3*10^{19} m^{-3})
- Increase of density (W7X) leads to reduction in temperature as would be expected
- Central ion temperature similar 1-1.5 keV

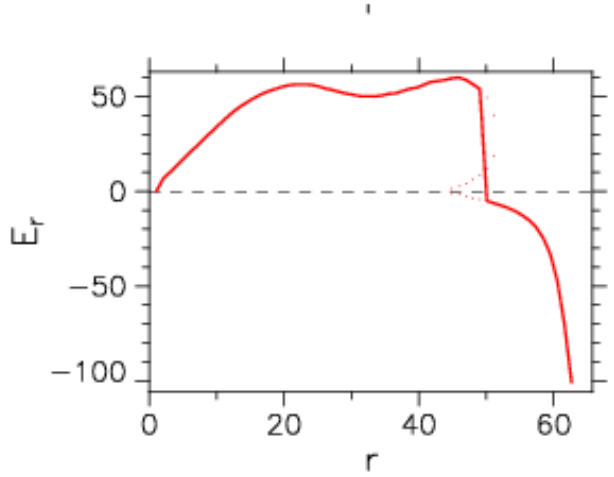
Configuration Comparison



- ε_{eff} similar in core plasma region (r/a < 0.3)
- less relevance of ε_{eff} once CERC is established (dominance of Er; see also W7X configuration scan)
- LHD strongly hollow profiles → neoclassic thermo-diffusion (?)
- LHD ripple increases strongly towards the edge (but may be less important as anomalous transport dominates r/a > 0.6)
- Neoclassical heat flux analysis is next step (need Ti profiles)
- Power balance (requires absorption profiles, etc.)

The radial electric field

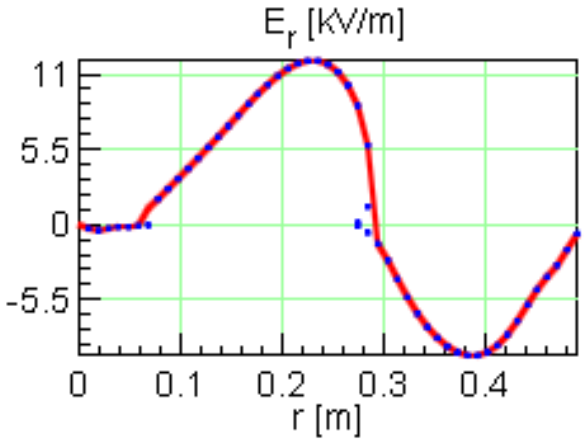
LHD



- #116899, similar to #127186

(Maasberg et al.)

W7-X



- #2016.03.09.010, similar to #2016.03.09.013

(Turkin et al.)

- Preliminary DKES results
- Both show strong positive radial electric field over a wide region
- Sharp transition to ion-root

Difficulties in inter-machine comparison

- Data access, data formats
- Availability and quality of data
- Finding corresponding discharges is a big challenge
- Collaboration on person-to-person basis → slow, low-priority
- Some data has to be requested individually

- **Suggestion:** shared folder for data collection and easy access to collaborators (modification/extension ISHPDB? MPCDF? ..??)
- Several ECRH experiments have been proposed for next LHD campaign (as well as W7X → coordination of identical experiments would be helpful)

Summary and Conclusions

- Collaboration has been initiated

- first potential discharge pair has been identified (2 MW)
- I am currently looking for other pairs (3 MW and 4 MW)

- Neoclassical heat-flux analysis and power balance should be next-step
  - Ti, Er profiles required (XICS)
  - ECRH absorption profiles (TRAVIS, LHDGAUSS)

- **Starting point of a more in-depth collaboration**
  - various experiment proposals for LHD submitted (Velasco, Alonso, Warmer, ..)
  - also further experiments at W7X (with divertor)
  - shared data / analysis for synergy effects
  - more detailed analysis: gyrokinetics, recycling, …
  - Input from colleagues across experiments welcome


WENDELSTEIN 7-X


IPP