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Scenario Development and Exploration of Operating Space for CFETR Plasma

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ABSTRACT

- Chinese Fusion Engineering Testing Reactor (CFETR) is aimed to bridge the gaps between ITER and the first commercial fusion power plant.
- Target plasma at flattop phase is modeled by 1.5-D simulations based on physics theories and efforts are made to optimize the performance of the scenarios
- A hybrid scenario with flat q profile in the deep core and a steady-state scenario with local reversed shear at mid-radius are developed.

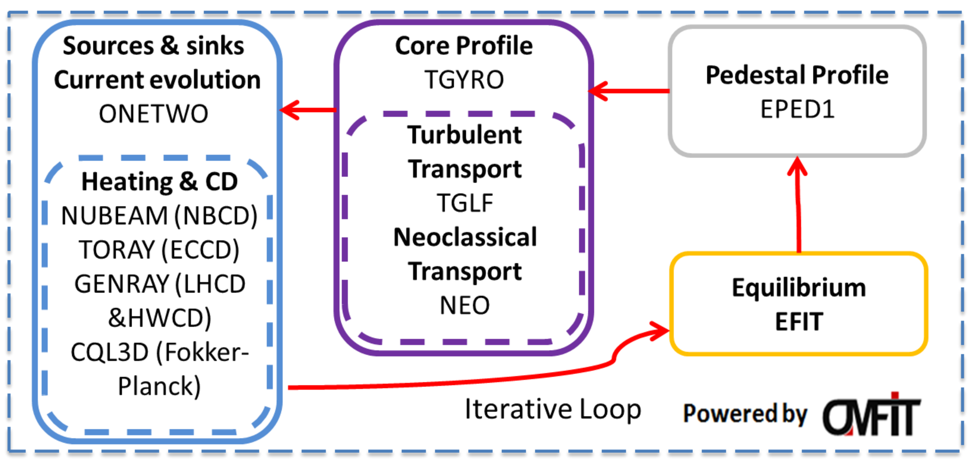
BACKGROUND

- The key mission of CFETR beyond ITER is to demonstrate the tritium self-breeding which requires to maintain the tritium breeding ratio (TBR) over about one at least a closed cycle for tritium fuelling with high fusion power. For this mission the concept design of CFETR proposed a long-pulse hybrid scenario and a steady-state scenario both with high fusion power ($P_{fus} \geq 1$ GW).
- There were unresolved gaps between the previous 0-D design developed by the system code study and the preliminary scenarios developed by the integrated modelling as shown in the last FEC [1]. Compared to the previous 0-D system studies the simulations showed more pessimistic performance and/or more challenging requirements on external actuators such as high external current drive power and deep fuelling. You may adjust size of these text boxes as needed. You may also change layout/colors/titles to best fit your paper.

METHODS

Core-pedestal coupling workflow in OMFIT used to model target plasma

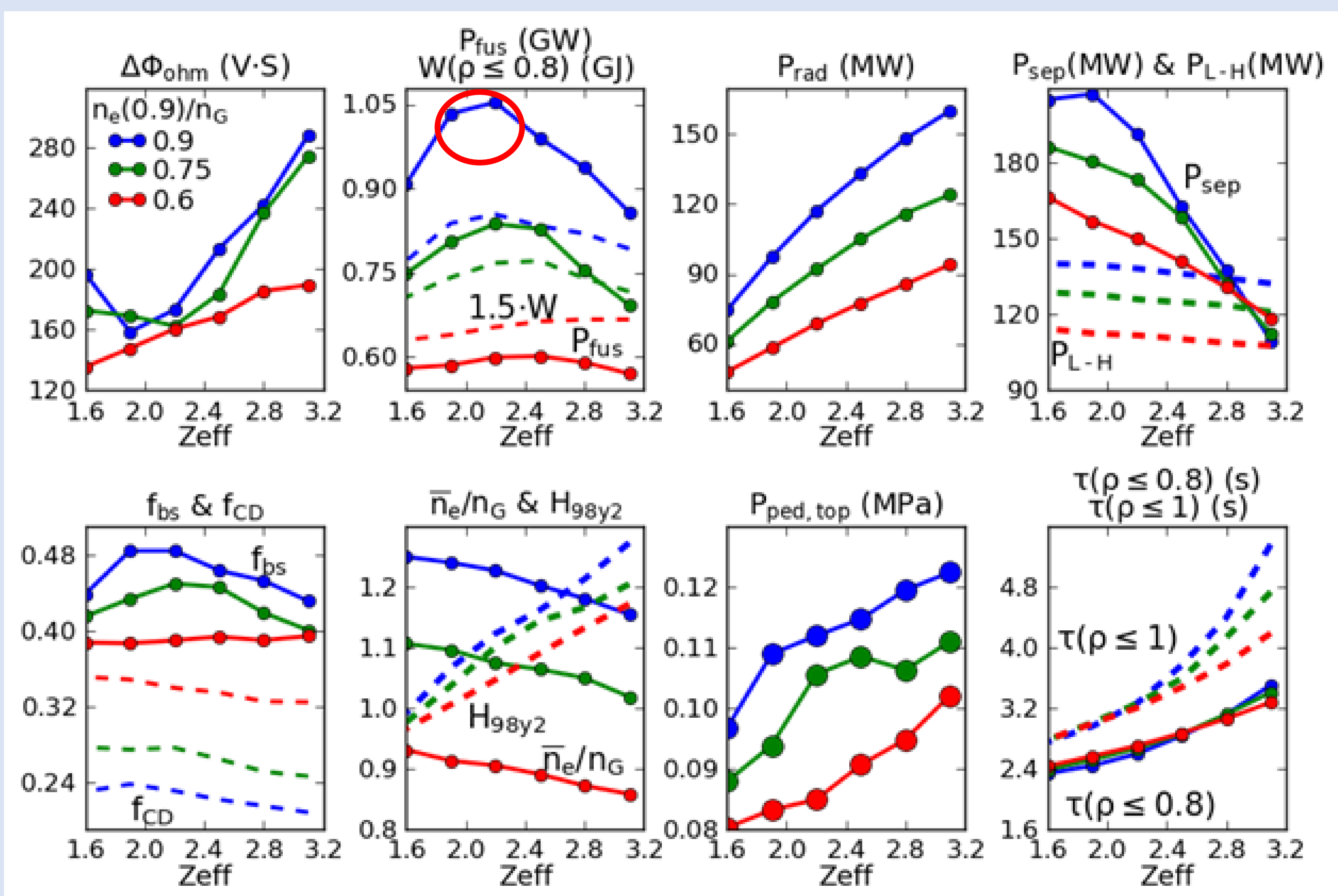
This section can be adjusted to address "challenges", "methods", "implementation" or others depending on contents of your paper. Each point should demonstrate clear view/vision of your topic.



Steps for optimization

Step 1. Optimize density and Zeff at pedestal

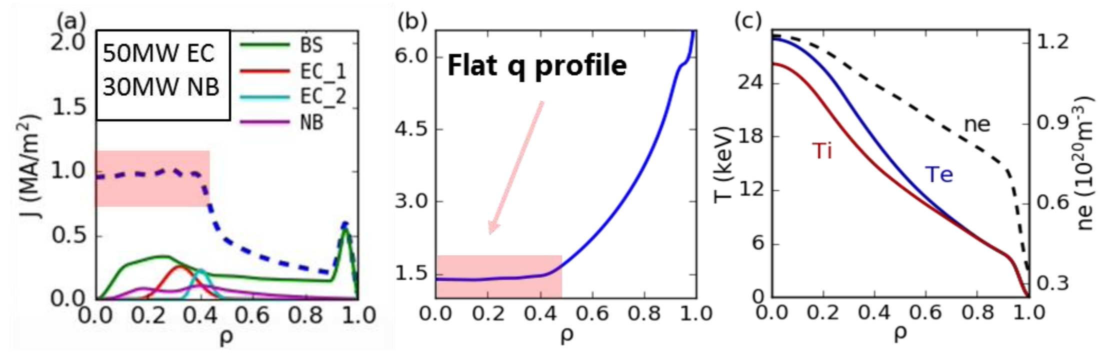
Step 2. Tailor q profile for each scenario with the H&CD methods with the highest priority in engineering design



Step 1. Scan of density and Zeff at pedestal to get the highest fusion power [2]

OUTCOME: Baseline case for CFETR hybrid scenario

- **Neutral beams and EC waves**
  - 1 MeV beams
  - 250 GHz EC waves
- **Enhanced confinement**
  - Flat q profile in core
  - Including EM stabilization effect

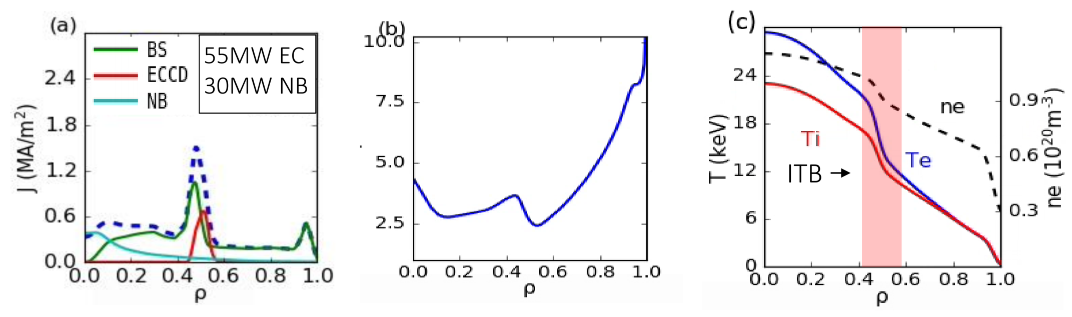


Comparison of plasma performance between different H&CD for CFETR hybrid scenarios [2]

Case Note	Baseline(EC)	LHCD	ICCD
P_{NB} (MW)	30	30	30
P_{EC} (MW)	50	↓40	↓30
P_{LH} (MW)	0	10	0
P_{IC} (MW)	0	0	20
f_{bs}	0.45	0.41	0.4
H_{98y2}	1.14	1.12	1.11
P_{fus} (MW)	952	↓819	↓788
Φ_{ohm} (VS)	250	↑284	↑322
$n_{e,line}(10^{20}/m^3)$	1.01	0.98	0.96

OUTCOME: Steady-state scenario

- **Neutral beams and EC waves**
  - Like hybrid scenario
- **Local reversed shear controlled by ECCD**
  - Enhanced confinement ITB*
- **No-wall beta limit $\beta_N = 3.0$**



P_{fus} (GW)	H_{98y2}	β_N/β_P	f_{bs}/l_i	I_p (MA)
1.0	1.33	2.97/2.5	0.78/0.8	10.5

CONCLUSION

- Target plasma at flattop phase is modeled by 1.5-D simulations based on physics theories and efforts are made to optimize the performance of the scenarios
- For Hybrid scenario
  - The *q* profile in the deep core region is flatten by the combination of NBCD and ECCD.
  - Replacement of ECCD by ICCD or LHCD yields performance degradation.
- For Steady-state scenario
  - Local reversed shear is controlled by localized ECCD to have an ITB at mid-radius.
  - All the destructive low-n modes are stable in the optimized position of the local reversed shear.
- Sensitive studies with the calibrated 0-D study show that the extension of plasma bulk towards LFS does not yield better plasma performance. [see the manuscript]

ACKNOWLEDGEMENTS / REFERENCES

[1] Zhuang G. et al 2019 *Nuclear Fusion* **59** (11) 112010.
[2] Chen J. et al 2021 *Nuclear Fusion* **61** (4) 046002.

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