INTEGRATED ASSESSMENT OF HIGH-PERFORMANCE SCENARIOS FOR HL-2M

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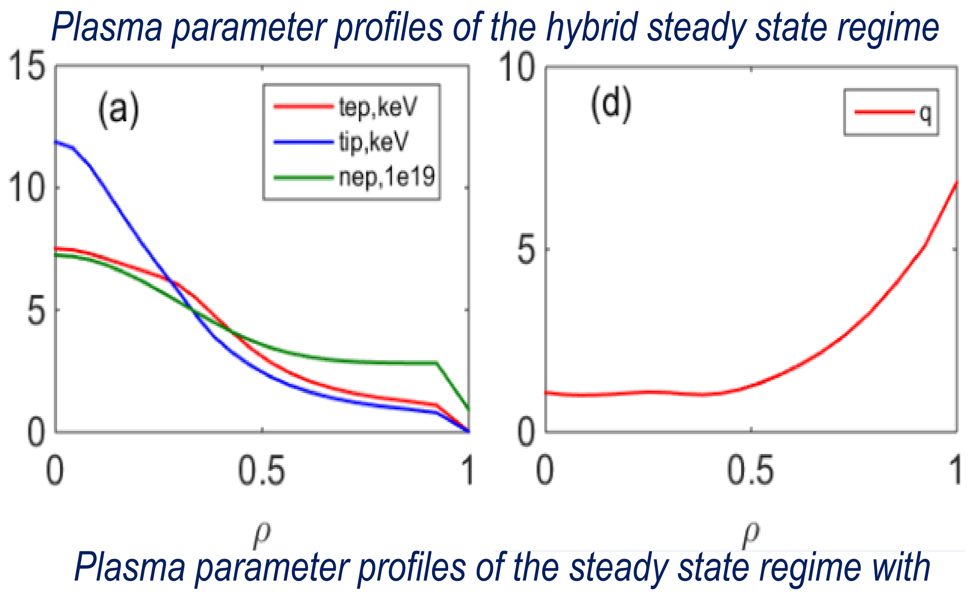
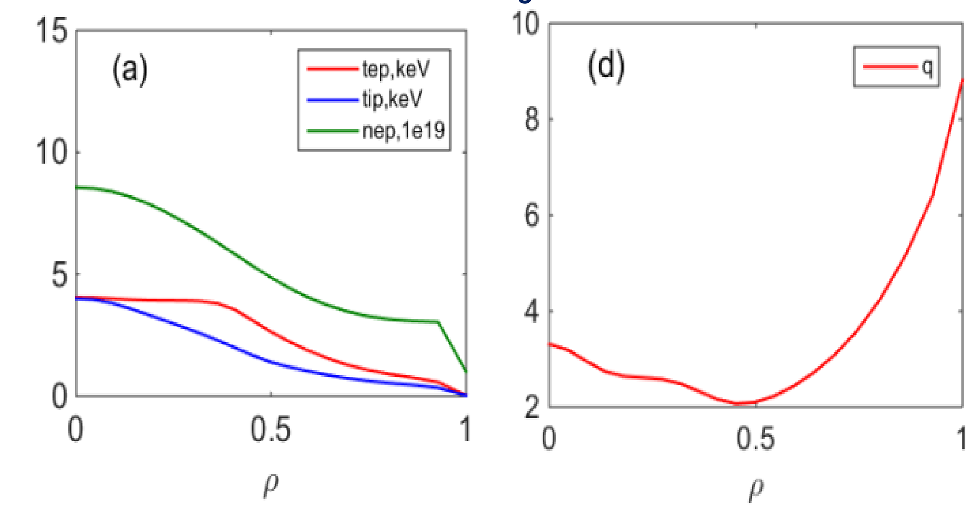
ABSTRACT

HL-2M is the new tokamak of SWIP, generating the first plasma in 2020. It is dedicated to support the critical physics and engineering issues of ITER and future fusion reactors. As one of the major missions of the machine, exploring key physics for the high-performance plasma is emphasized. This paper will firstly introduce the assessment of high-performance scenarios analyzed by Integrated modeling. Simulation results show that the high-performance operation can be realized at plasma current as high as 2.5 mega-ampere. In such regime, the normalized beta can reach 3, the triple-product can reach about 10^{20}. In a moderate Greenwald density fraction, the central ion temperature can reach 10keV. These allows HL-2M to own the capability to carry out ITER relevant plasma physics. In support of ITER pre-fusion phase operation (Hybrid and Steady State), the advanced scenarios, such as the hybrid and the steady state regimes can be achieved. For the non-inductive regime, the normalized beta can reach 3.4, and the confinement enhancement factor can exceed 1.3.

Plasma parameter profiles of the hybrid steady state regime



Plasma parameter profiles of the steady state regime with a reversed magnetic shear



- ❑ ***Advanced scenarios***
- **Hybrid scenario : I_p=1.0~1.4MA,** f_G~0.5 by combining NBCD with ECCD or ECCD+LHCD. In Hybrid regimes, the fractions of bootstrap current f_{BS} and total non-inductive current f_{ni} are between **30%~45%** and **70%~90%**, **respectively; β_N can reach 2.5 with $H_{98(y,2)}$~1.1**
- **Full non-inductive regimes,** such as the hybrid steady state regime and the regime with a reversed magnetic shear, can reach **1MA plasma current with f_{BS}>60%, $H_{98(y,2)}$~1.3, β_N >3.**

INTRODUCTION

❑ **HL-2M is able to address the following key physics and technology issues :**

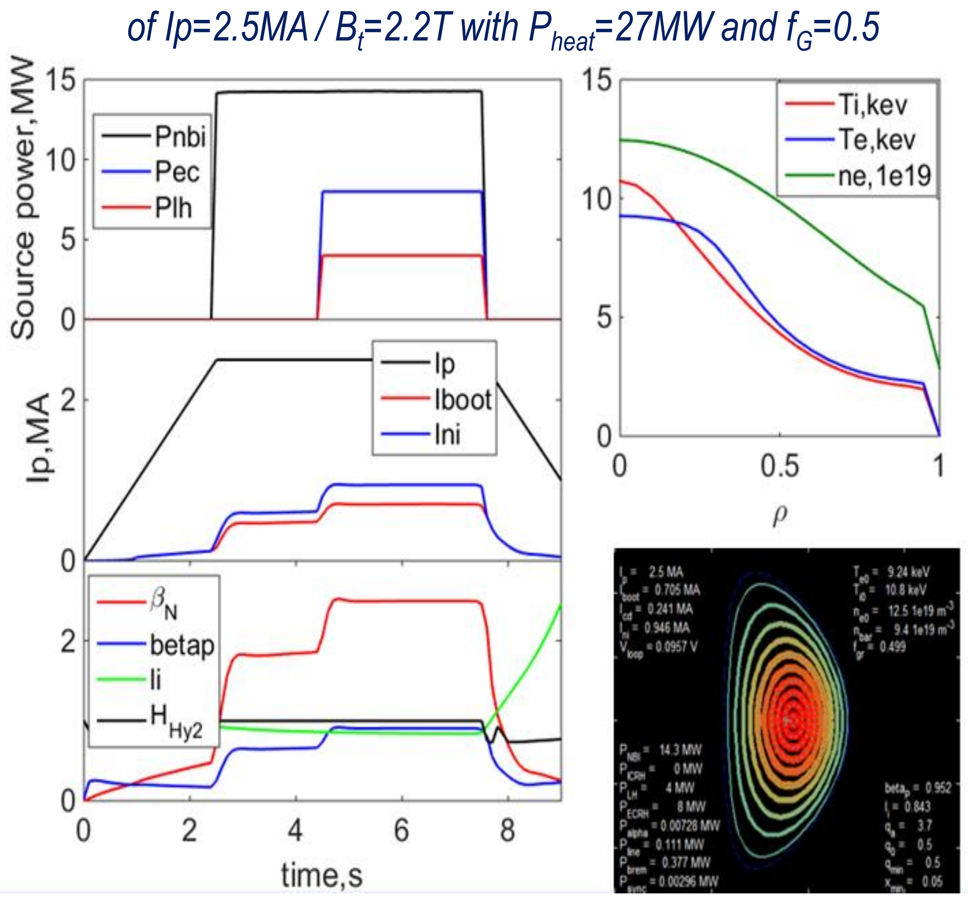
- Tests and qualification of various advanced divertor concepts, such as Snow Flake (SF) and Tripod, on both physics and technological aspects;
- Tests and validation of high heat flux plasma-facing components;
- Investigation of advanced plasma physics with high performance, and design of scenarios compatible with advanced divertor configurations.

❑ Three Heating & Current Drive (H/CD) systems with maximum power of 27MW, including 15MW NBI, 8MW ECRF and 4MW LHW, support high-performance operation.

CAPABILITY ASSESSMENT OF DN CONFIGURATION

The operation capabilities (such as the inductive, hybrid and full non-inductive regimes), based on the double-null (DN) configuration with elongation of 1.8, is assessed by METIS. During the simulation, the engineering limits, of the auxiliary heating duration and of the heating loads in the coils, are assumed to be free. Thus, performing H-mode plasmas at these conditions is limited by the available poloidal flux of 14Wb.

Waveform and profiles of plasma parameters in the regime of Ip=2.5MA / B_t=2.2T with P_{heat}=27MW and f_G=0.5



❑ ***Conventional inductive regime* (*Ip*=2.5MA, B_T=2.2T)**

- **High performance operation with β_N ~ 3 (P_{heat} ~ 25MW(27MW))**
- **$n(0)T_i(0)\tau$ can reach 10^{20} m^{-3}skeV level**
- **Central plasma temperature can reach around 10keV, with f_G=0.5**

Parameters	Conventional inductive				
	C1	C2	C3	C4	C5
I_p (MA) / B_T (T)	2.5 / 2.2	2.5 / 2.2	2.5 / 2.2	2.5 / 2.2	2.5 / 2.2
κ / δ	1.8 / 0.5	1.8 / 0.5	1.8 / 0.5	1.8/ 0.5	1.8 / 0.5
a / R (m)	0.65 / 1.78	0.65 / 1.78	0.65 / 1.78	0.65 / 1.78	0.65 / 1.78
f_G	0.6	0.6	0.6	0.6	0.5
P_{NBI} / P_{EC} / P_{LH} (MW)	15 / 0 / 0	15 / 8 / 0	15 / 8 / 2	15 / 8 / 4	15./ 8 / 4
X_{EC} / X_{LH}	-/ -	0.3 / -	0.3 / 0.7	0.3 / 0.7	0.3 / 0.7
q_{95}	3	3	3	3	3
β_p	0.7	0.9	1	1	1
β_N	2.2	2.7	2.8	2.9	2.8
f_{BS} / f_{ni}	0.18 / 0.22	0.25 / 0.29	0.26 / 0.32	0.28 / 0.35	0.28 / 0.37
$T_e(0)$ / $T_i(0)$ (keV)	6.1 / 8.1	8.3 / 9.0	8.5 / 9.2	8.7 / 9.4	9.2 / 11
W_{th} (J)	2.6	3.2	3.3	3.5	3.3
$H_{98(y,2)}$	1	1	1	1	1
G	0.26	0.31	0.32	0.33	0.31
$n(0)\tau T_i(0)$ ($10^{20}m^{-3}$skeV)	2.0	1.9	1.8	1.8	1.7

PRELIMINARY ANALYSIS OF SN PLASMA PERFORMANCE

The performance of the standard single-null plasma with elongation of 1.5 and triangularity of 0.43 is further analyzed by the integrated modelling suite—CRONOS with QLKz transport model.

❑ ***Conventional inductive regime* (*Ip*=1.8MA, B_T=2.2T *with* f_G=0.69)**

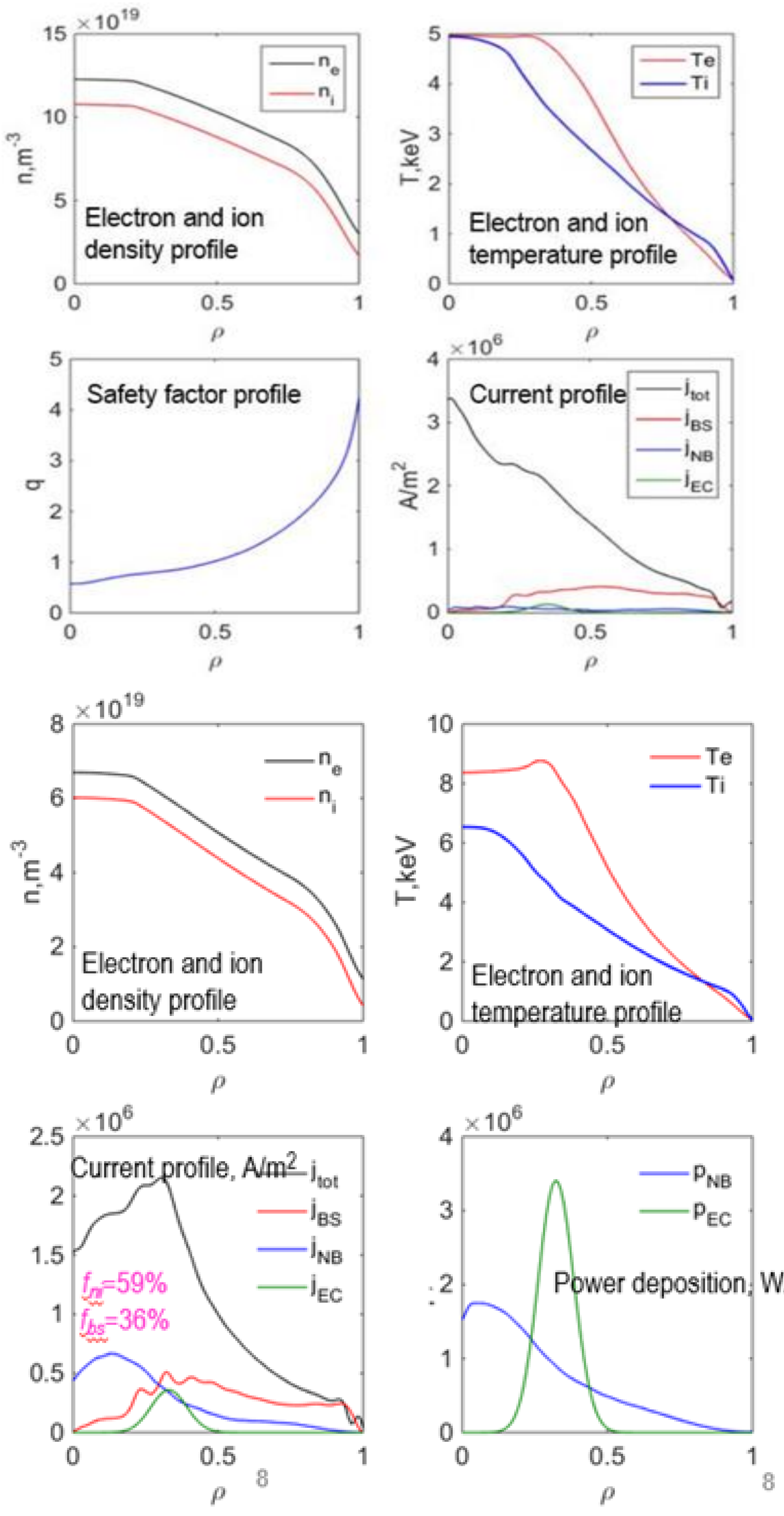
H&CD:15MW NBI+8MW ECRF

- **q_{95} ~ 3.0.**
- The thermal energy of the plasma **W_{th} reaches 2.0MJ** with the high **β_N of 3.0**
- Both the ion and the electron temperature of the center can reach around **5keV**

❑ **Hybrid regime (Ip=1.4MA,B_T=2.2T *with* f_G=0.5)**

H&CD: 8MW NBI+8MW ECCD

- **q_{95} ~ 3.9.**
- **f_{NI} ~ 0.6.**
- **$H_{98(y,2)}$ ~ 1.3.**
- The ion and the electron temperature of the center can reach **6.4keV** and **8.5keV**, respectively.
- The thermal energy of the plasma reaches **1.4MJ with β_N of 3.1.**



SUMMARY

- ✓ **HL-2M operation capability with DN plasma is assessed by METIS**
- ✓ **Performance of SN plasma is preliminary analyzed by CRONOS with QLKz transport model.**
- ✓ **Results indicate that HL-2M is a high-performance plasma research platform for the next-step fusion devices. It have the capability to carry out ITER relevant plasma physics, supporting ITER pre-fusion phase operation.**

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