Preliminary consideration on basis and requirements of core plasma for next CFETR

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Input for core plasma

- **Fusion power and gain、 neutron load on the wall、plasma （burning) duration、etc**
- **Physics basis（operation scenarios、stability margins、plasma control、etc）**

➢ ITER baseline: type I ELM-H mode (hybrid, RS)

- **constrains（heat load on divertor plates，cost, nuclear license）**

Tools for core plasma design

- **Zero dimensional model**

➢ Based on the scaling rules

- **One dimensional model**

➢ Based on existing transport models (equilibrium, transport, stabilities)

- **Scale from existing plasmas**

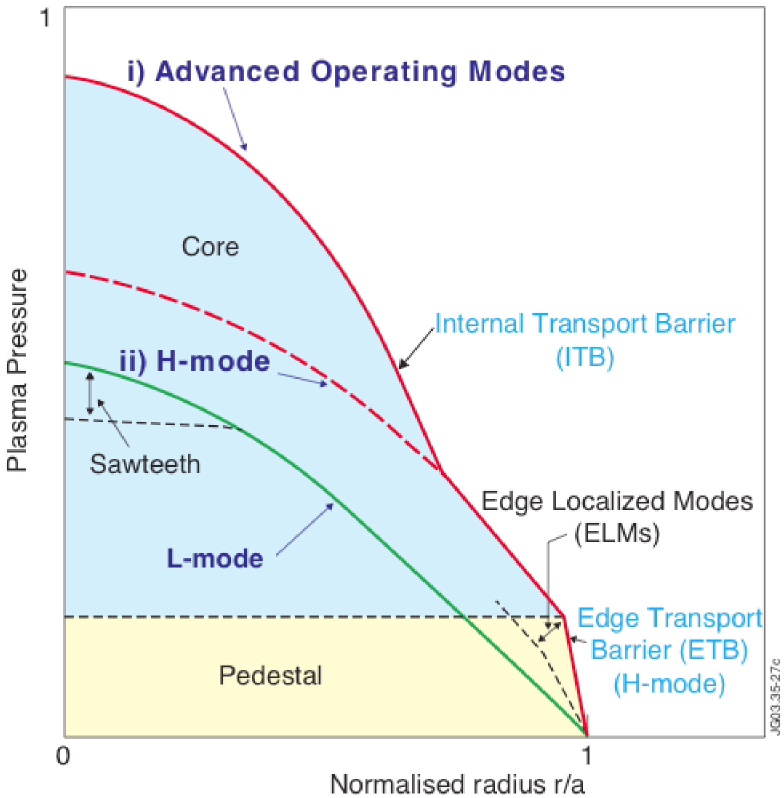
➢ Based on physical relations and existing experiments

Benchmark from each other

Principles for Core plasma design

- **To assure the success of the baseline targets:**
  - Based on already proven physics
  - Operation within all stability boundaries (conservative implementations)
- **To keep capabilities for very advanced scenarios**
  - Explore newest advances of physical understanding and technology developments
- **To keep flexibilities for research of advanced physics and developments of new technologies**

Operation modes



$$\beta_N \equiv 100\beta a B_0 / I_p \leq 3$$

$$n_{20} \leq n_{GR} \equiv 0.27 I_p / a^2$$

$$q_{95} \geq 3$$

- f_{α}>50%, f_{bs}>50%, (~80% for AT)?
- Type I ELM-H mode as baseline?
  - ➢ Robust (easy access)
  - ➢ High pedestal allows fusion relevant temperatures in most of the volume
  - ➢ Heat load due to ELM crash
  - ➢ Confinement strongly degrades with heating power ($\tau \sim P^{-0.69}$)

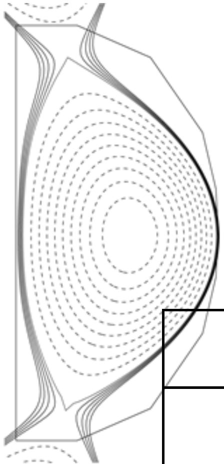
- AT modes for steady-state operation to demonstrate reactor relevant physics and technology feasibilities
  - ➢ Need further advance of physics

Need assessment of synergy effect of operation mode with heating/current drive, control, PWI, etc

Conservative examples $n_{20} = 0.85 n_{GR}$

scenarios	Conv. High P	Conv. Low P	Conv. High P	Conv. Low P	AT Low P
I_p (MA)	9	9	10	10	7
P_{aux} (MW)	80	50	80	50	50
q_{95}	3.5	3.5	3.0	3.0	4.55
Fusion power (MW)	*198*	*149*	*316*	*244*	*192*
Q	*2.47*	*2.98*	*3.95*	*4.87*	*3.84*
β_T	2.66	2.31	3.36	2.95	2.62
β_N	*2.19*	*1.90*	*2.40*	*2.11*	*2.81*
β_P	0.92	0.80	0.87	0.77	1.53
I_{bs}/I_p (%)	*30.1*	*26.2*	*28.6*	*25.1*	*50.2*
τ_{E_92} (s)	1.58	2.05	1.67	2.13	1.40
τ_{E_98Y2} (s)	1.38	1.82	1.47	1.90	1.19
P_n/A_{wall} (MW/m^2)	*0.48*	*0.36*	*0.76*	*0.59*	*0.46*

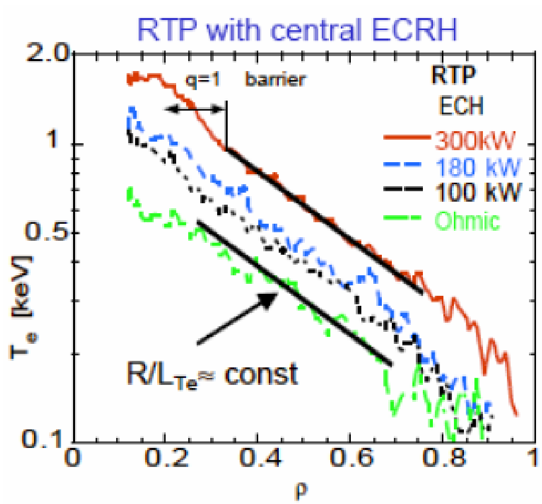
R(m)=5, a(m)=1.5, B(Tesla)=5； κ=1.75, δ=0.4； α_n=0.5, α_T=1； Vp(m^3)=389;

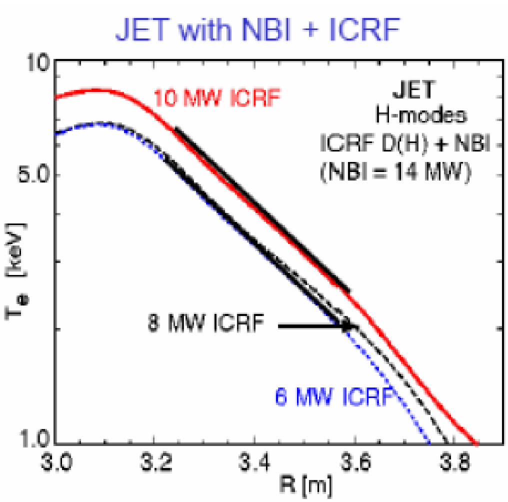


AT examples using the physics based modeling

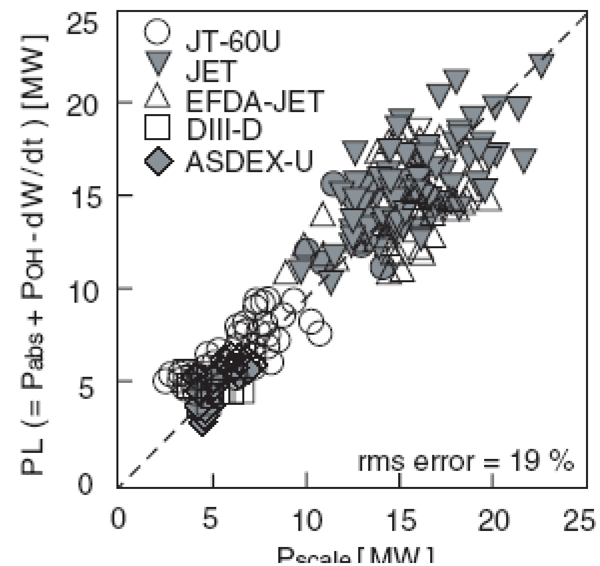
Case	A1	A2	A4	A5	B1	B2	B3	B4
Ip (MA)	8.0	8.0	8.0	8.0	6.0	6.0	6.0	6.0
β_N	2.52	3.57	4.01	4.45	2.51	3.04	3.58	3.96
P_{fus} (MW)	268	426	480	526	152	204	248	276
l_i	0.97	0.95	0.92	0.9	1.14	0.96	0.96	0.98
q_0	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
q_{95}	3.06	3.15	3.23	3.27	4.41	4.68	4.64	4.78
$p_0 / \langle p \rangle$	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.8
$\beta_{N,ped}$	0.43	0.48	0.51	0.53	0.41	0.42	0.43	0.44
I_{bs} / I_p (%)	39.1	54.8	61.9	68.8	46.9	61.2	70.0	75.6

AT physics?

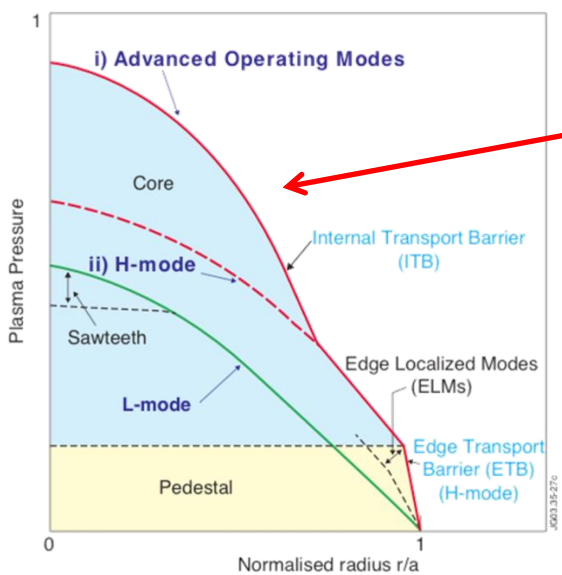




P_{th} for ITB



$$P_{\rm Th}^{\rm ITB(i)} = 3.14 n_{19}^{0.9} a^{2.13} \kappa_{95}^{1.34} (0.2 + \delta_{95})^{-0.15} B_t^{0.23}$$



stiffness can be mitigated by rotation, ITB formation and sustainment

Ion heating dominated

P_{th}^{ITB} ≤ 30MW on ions
However, power preferentially deposit on electrons for reactor relevant plasma