

Impact of High Field & High Confinement on L-mode-Edge Negative Triangularity Tokamak (NTT) Reactor

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“NTT” is a unique reactor concept based on “power-handling-first” philosophy by locating long-leg (~2.7m) divertor at outboard side with negative triangularity $\delta < 0$ and making flux tube expansion to maximize heat exhaust surfaces (grazing angle $\sim 2^\circ$).

Our previous design ($I_p=21\text{MA}$, $A=R_p/a_p=3$, $R_p=9\text{m}$, $HH=1.12$, $B_t=5.86\text{T}$) uses standard magnet design based on the wedge support and maximum field is limited to 13.6T due to stress limit 800MPa and large reactor size. It allows adoption of currently available Nb₃Sn superconductor at 4.5K as well as Bi₂122/Pb high T_c superconductor at 20K. NTT configuration has technical merits of having space in the inboard except narrowest point to place the blanket piping and auxiliary systems such as pellet injector line and ECH waveguides. Outward placing of the divertor is favorable for pumping conductance.

Parameter studies on impact of high B_t and HH for A=3, 3.5 are shown where $HHI_pA=69.3\text{MA}$, $n/n_{GW}=0.85$ and $q_{cy}=3.5$ are fixed. The reduction of major radius to $R_p=7\text{m}$ is possible with improved confinement ($HH=1.5$) while B_{max} is nearly constant. In this case, fusion power is reduced to $P_f=2\text{GW}$ and the neutron wall load stays almost constant $q_n \sim 1.4\text{--}1.5\text{MW/m}^2$ while the normalized beta β_N becomes higher $\beta_N=2.9$. For fixed $HH=1.2$, higher B_{max}=16T enables to reduce major radius to $R_p=7\text{m}$. In this case, fusion power P_f and neutron wall load q_n increases while β_N stays almost constant. For A=3.5, we observe similar trend. The plasma volume is smaller ($V_p \sim 1000\text{m}^3$) compared with A=3 case ($V_p \sim 1500\text{m}^3$). But requirement for B_{max} for fixed $HH=1.2$ becomes rather high B_{max}=19.5T. With improved confinement ($HH=1.5$), reduction of major radius to $R_p=7\text{m}$ is possible leading to $I_p=13.3\text{MA}$, $B_t=7.53\text{T}$, $n=0.9 \times 10^{20} \text{ m}^{-3}$, $P_f=1.9\text{GW}$, B_{max}=15.5T, PCD=115MW ($\eta_{CD}=0.5 \times 10^{20} \text{ A/m}^2\text{W}$ is assumed). We made configuration design for this case and the equilibrium calculation. Extended wedge support allows σ_{max} within 800MPa at 4.5K. It is concluded that both high magnetic field and high confinement are important for the realization of reasonably compact NTT fusion reactor as future R&D.

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Primary author: Dr KIKUCHI, Mitsuru (QST)

Co-authors: Dr CHEN, Dehong (INEST-CAS); Dr LI, Jiaxian (SWIP); Prof. IMADERA, Kenji (IAE, Kyoto University); Prof. VILLARD, Laurent (SPC-EPFL); Dr AUSTIN, Max (IFS-University of Texas); Dr SAUTER, Oliver (SPC-EPFL); Dr MEDVEDEV, Sergei (KELDYSH INSTITUTE OF APPLIED MATHEMATICS); Prof. TAKIZUKA, Tomonori (Osaka University); Dr ANDO, Toshinari (Ex-JAEA); Prof. KISHIMOTO, Yasuaki (IAE, Kyoto University)

Presenter: Dr KIKUCHI, Mitsuru (QST)

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