Progress toward fully noninductive discharge operation in DIII-D using off-axis neutral beam injection

J.R. Ferron,[1, a)] C.T. Holcomb,[2] T.C. Luce,[1] J.M. Park,[3] P.A. Politzer,[1] F. Turco,[4] W.W. Heidbrink,[5] E.J. Doyle,[6] J.M. Hanson,[4] A.W. Hyatt,[1] Y. In,[7] R.J. La Haye,[1] M.J. Lanctot,[1] M. Okabayashi,[8] T.W. Petrie,[1] C.C. Petty,[1] and L. Zeng[6]

[1)] *General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA*

[2)] *Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, CA 94550-9234, USA*

[3)] *Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*

[4)] *Columbia University, 116th St and Broadway, New York, NY 10027, USA*

[5)] *University of California, Irvine, University Dr., Irvine, CA 92697, USA*

[6)] *University of California, Los Angeles, PO Box 957099, Los Angeles, CA 90095-7099, USA*

[7)] *FAR-TECH, Inc., 10350 Science Center Dr., San Diego, CA 92121-1136, USA*

[8)] *Princeton Plasma Physics Laboratory, PO Box 451, Princeton, NJ 08543-0451, USA*

(Dated: 12 August 2013)

The initial experiments on off-axis neutral beam injection into high noninductive current fraction ($f_{\rm NI}$), high normalized pressure ($\beta_{\rm N}$) discharges in DIII-D [J.L. Luxon, Fusion Sci. Technol. **48**, 828 (2005)] have demonstrated changes in the plasma profiles that increase the limits to plasma pressure from ideal low-n instabilities. The current profile is broadened and the minimum value of the safety factor ($q_{\rm min}$) can be maintained above 2 where the profile of the thermal component of the plasma pressure is found to be broader. The off-axis neutral beam injection results in a broadening of the fast-ion pressure profile. Confinement of the thermal component of the plasma is consistent with the IPB98(y,2) scaling, but global confinement with $q_{\rm min} > 2$ is below the ITER-89P scaling, apparently as a result of enhanced transport of fast ions. A 0-D model is used to examine the parameter space for $f_{\rm NI} = 1$ operation and project the requirements for high performance steady-state discharges. Fully noninductive solutions are found with $4 < \beta_{\rm N} < 5$ and bootstrap current fraction near 0.5 for a weak shear safety factor profile. A 1-D model is used to show that a $f_{\rm NI} = 1$ discharge at the top of this range of $\beta_{\rm N}$ that is predicted stable to $n = 1$, 2 and 3 ideal MHD instabilities is accessible through further broadening of the current and pressure profiles with off-axis neutral beam injection and electron cyclotron current drive.

PACS numbers: 52.55.-s,52.55.Fa

[a)]Electronic mail: ferron@fusion.gat.com