The Ignitor Project and the Columbus Proposal

Innovative experiments to prove ignition by fusion reactions for the first time

An important problem in the physics of high energy plasmas is to understand the stability and transport properties of a self-organized thermal D-T fusing plasma under conditions where the heating by the fusion-produced particles, with multi-MeV energies, can compensate all forms of energy loss. These conditions correspond to achieving (real) ignition. Reaching ignition, where the so-called thermonuclear instability can develop and be controlled, can be regarded as the scientific demonstration of a self-sustained fusion reactor. The high magnetic field technologies adopted for an experiment like Ignitor (Fig.1), the first proposed and designed to reach ignition and the only magnetic confinement concept maintaining this goal at this time, and the physics that it is expected to uncover, are directly relevant to the design of future fusion reactors.

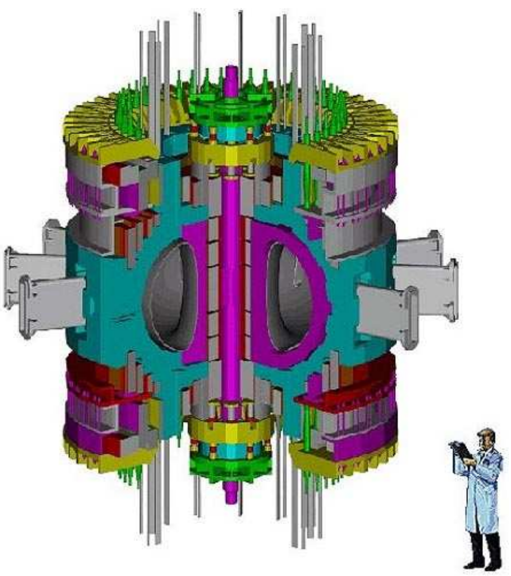

Fig. 1 Ignitor machine

The Ignitor project has been envisioned as a key component of a spectrum of experiments that are needed to explore the physics of fusion burning plasmas up to ignition. The Columbus program is proposed as a U.S. counterpart to the Ignitor project that is ongoing in Italy and to be complementary to it. In particular, Columbus has a larger volume than Ignitor by about 50%.

Ignitor is designed so that the burning phase exceeds all the intrinsic physical time scales, and they specifically address the main issues that should be resolved in present-day research on nuclear fusion: demonstration of ignition, the study of the physics of the ignition process, and the heating and control procedures for a burning plasma. The first exploration of fusion burn conditions in tritium-poor plasmas can also be conducted, with significant production of power from D-^{3}He reactions.

The machine is characterized by a complete structural integration of their major components. "Split" central solenoids are adopted to provide the flexibility to produce the expected sequence of plasma equilibrium configurations during the plasma current and pressure rise. The structural concept upon which the machine is based involves an optimized combination of "bucking" between the toroidal field coils and the central solenoid with its central post, and "wedging" between the inner legs of the toroidal field magnet coils and between the C-clamps in the outboard region. The machine core, consisting of the copper TF coils, the major structural elements (C-clamps, central post, bracing rings) and the plasma chamber, is designed to withstand the forces produced within them with the aid of a radial electromagnetic press when necessary. This ensures that the inner legs of the TF coils possess a sufficient degree of mechanical strength to withstand the electrodynamic stresses, while allowing enough deformation to cope with the thermal expansion that occurs during the plasma discharge. The entire machine core is enclosed by a cryostat. All components, with the exception of the vacuum vessel, are cooled before each plasma pulse by means of He gas, to an optimal temperature of 30 K.

The ENEL center of Rondissone, near Turin, has been chosen on the basis of its credits. Rondissone is a major node of the European electrical grid and has been analyzed and authorized to accept loads corresponding to the highest plasma currents and fields in Ignitor.

Table I. Reference Parameters of the Ignitor Device and the Columbus Concept

PARAMETER	Ignitor	Columbus
Major radius R_0	1.32 m	1.50 m
Minor radii $a \times b$	0.47 m × 0.86 m	0.535 m × 0.98 m
Aspect ratio A	2.8	2.8
Elongation κ	1.83	1.83
Triangularity δ	0.4	0.4
Vacuum Toroidal Field B_T at $R = R_0$	$\lesssim$ 13T	$\lesssim$ 12.6 T
Toroidal Current I_p	$\lesssim$ 11 MA	$\lesssim$ 12.2 MA
Poloidal Current I_θ	$\lesssim$ 9 MA	$\lesssim$ 10 MA
Paramagnetic Field Produced by I_θ	$\simeq$ 1.4 T	$\simeq$ 1.4 T
Mean Poloidal Field $\overline{\overline{B}}_p \equiv I_p / \left(5\sqrt{ab}\right)$	$\simeq$ 3.4 T	$\simeq$ 3.4 T
Confinement Strength $S_c \equiv \overline{\overline{B}}_p I_p$	$\lesssim$ 38 MN/m	$\lesssim$ 41.5 MN/m
Toroidal Current Density $\langle J_\Phi \rangle \equiv I_p / (\pi ab)$	$\lesssim$ 9.3 MA/m^2	$\lesssim$ 7.4 MA/m^2
Maximum Poloidal Field B_{pM} $(R < R_0)$	$\lesssim$ 6.5 T	$\lesssim$ 6.5 T
Edge Magnetic Safety Factor q_Ψ	3.6 @ $I_p \simeq$ 11 MA	3.6 @ $I_p \simeq$ 12.2MA
Magnetic Flux Swing	$\lesssim$ 33 Vs	$\lesssim$ 37.5 Vs
Plasma Volume V_0	$\simeq$ 10 m^3	$\simeq$ 14.5 m^3
Plasma Surface S_0	$\simeq$ 34 m^2	$\simeq$ 44 m^2

Web sites: http://ignitor.rle.mit.edu **For more information write to** ***coppi@mit.edu*** **or** ***ignition@mit.edu***
http://www.frascati.enea.it/ignitor

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