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Technical Benefits of the PROTO-SPHERA Confinement Configuration

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The PROTO-SPHERA experiment can produce plasma spherical tori with a simply connected configuration (the centerpost is practically implemented by the plasma itself) and a high confinement efficiency ($\beta \longrightarrow 1$). Such configurations are obtained from the self-organization of a plasma arc (screw pinch) in a magnetostatic field. This approach leads to several technical and economic advantages, that even exceeded the initial theoretical expectations.
The experimental system can be operated by only 3 groups of power supplies (for cathode heating, poloidal field and pinch, respectively) with a virtually constant current and with a limited demand of electrical energy. In fact, the recent experiments showed that the plasma tends to a toroidal (tokamak-like) shape even without the very fast current derivatives predicted in the initial design. The plasma current is induced and confined without a toroidal magnet and without variations in the magnetic flux and in the poloidal coil currents. The maximum voltage applied in the structure, even at the arc breakdown, does not exceed 350 V. A high temperature can be reached without additional heating and current drive systems.
Axisymmetric double null configurations with electron density in the order of 1020 m-3 were already observed. The experiments also showed that the PROTO-SPHERA configurations are stable as long as the pinch voltage is applied. The plasma is not terminated nor disrupted even in presence of sudden deformations of the pinch. Therefore, the set-up is consistent without any further coils or radiofrequency sources to cope with plasma instabilities.
The vessel is cylindrical and it can be totally opened and closed in few days for maintenance and modifications. For example, the adjustment of the poloidal field by the introduction of new internal and external coils is relatively simple, as already done with several external coils during the experimental campaigns. Since 2019 the middle part of the cylindrical vessel is non-conducting and transparent in order to avoid undesired couplings for the plasma arcs or for the magnetic field produced by the external coils and in order to make the plasma configuration clearly visible for the researchers and for the diagnostic tools.
The insertion and expulsion of elements, as pinch current or gas, through the configuration follow a simple and well defined path. The fusion products could be ejected through a magnetic nozzle on the cylinder axis (with possible applications in spacecraft propulsion).

Primary authors: LAMPASI, Alessandro (ENEA); PROTO-SPHERA GROUP

Presenter: LAMPASI, Alessandro (ENEA)

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