Status of the PROTO-SPHERA experiment: full current/full duration plasma tori production and sustainment and insights for Phase-2

P. Micozzi[1] and PROTO-SPHERA Group

Centro Ricerche ENEA, Frascati C.P. 65, Rome, Italy
[1]*E-mail:* paolo.micozzi@enea.it

The PROTO-SPHERA experiment is based upon a new magnetic confinement scheme, which aims at producing – in its Phase-2 – a Spherical Torus (with $I_{ST} \leq 300$ kA) around a Plasma Centerpost (a Screw Pinch with $I_e=70$ kA) fed by electrodes of annular shape. The Phase-1 of PROTO-SPHERA, aimed of obtaining a stable Hydrogen Plasma Centerpost, lasting 1 sec with $I_e=10$ kA, was successfully ultimate at the begin of 2018. In 2019 the PROTO-SPHERA experiment has been largely modified: a new insulating/transparent vacuum chamber in PMMA substitute the START Aluminum vessel and 6 internal PF coils has been inserted inside the machine: this is the so-called Phase-1.5 of the machine devoted to form and sustain a torus around the central Screw Pinch, although with $I_e=10$ kA.

The results obtained in the 2020-2021 campaign has been confirmed in the 2024 campaign, that is the last performed in the present location: PROTO-SPHERA will be moved in a new experimental hall in Frascati, more suitable for the Phase-2 of the experiment. Clear evidence of nested magnetic surfaces inside the tori was still obtained, and the plasma discharge duration is increased up to 1 sec (the power supplies limit) with $I_e=10$ kA by solving the problems of plasma pollution that limited the duration to 0.3 sec in the previous campaigns. The visible light images from the 6 medium-speed cameras (600 fps) located outside the (transparent) vacuum vessel allow for a full 3D reconstruction of the formation phase as well as of the sustained phase. The value of the toroidal current I_{ST}, estimated from vertical magnetic field measured by the Hall probes located in proximity of the plasma, agrees with the value that can be derived from the distance between the X-points, as observed on the visible images. There is evidence that the torus quality (and even existence) is correlated to the presence of a vertical current that surround it also on the external part and not only on the main Screw Pinch. In the 2024 campaign this external current is provided by spurious current paths in the PF coils casing, while in the 2020-2021 campaign was provided by a lack of insulation of the lower divertor plate that acted as an electrode. The Phase-2 of PROTO-SPHERA requires some substantial modification of the machine. A new hollow cathode design shall be necessary as well as a new and more robust design of the divertor plates (connected to a new power supply) that shall also act as electrodes in order to provide the current that has to flow on the external path of the torus.