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Present and future plans of PROTO-SPHERA

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PROTO-SPHERA is an axi-symmetric magnetic confinement experiment, just like a spherical Tokamak: toroidal and poloidal magnetic fields (i.e. a plasma toroidal current IST) are required inside a spherical torus to contain the plasma. PROTO-SPHERA produces both fields while removing the two central metal conductors: the central toroidal rod and the central ohmic transformer; they are replaced by a plasma centerpost discharge, with helical magnetic force lines, carrying an electrode current I_e , fed by DC electrodes inside the vacuum vessel. PROTO-SPHERA however is not a Spheromak, as no metal flux conserver is present around the spherical plasma. While the presence of the toroidal field in PROTO-SPHERA is obvious, provided that the electrodes produce a stable current carrying centerpost plasma, the sustainment of the current carrying torus by DC electrodes is not obvious and it has been the first achievement of the experiment. In its initial Phase-1 (2014-2018) PROTO-SPHERA was built with 8 magnetic PF coils inside the vacuum vessel, to shape the plasma centerpost only; the electrode current reached in Hydrogen its Phase-1 limit: $I_e=10$ kA. By adding 4 PF coils outside the vacuum vessel, the first “thin” confined tori (that fill just 7% of the total plasma volume), endowed with divertors emerging from magnetic X-points, were formed and sustained, with $I_e=10$ kA and $IST=7$ kA. The $IST=7$ kA toroidal current could be maintained in quasi-steady state as long as the anode-to-cathode DC voltage was applied (1 sec): it is highly plausible that the magnetic reconnections, observed around the X-points, were able to provide the steady-state current drive to the high density ($>10^{20}$ m⁻³) confined tori. In the 2019 intermediate Phase-1.5, with I_e still limited to 10 kA, the confined tori will be compressed to low aspect-ratio, and their toroidal plasma current will be increased to $IST=20-40$ kA: 6 provisional internal PF compression coils have been added, bringing the total number of PF coils (internal and external) to 18. In Phase-2 (2021) the centerpost plasma current I_e will grow from 10 kA to 70 kA; the spherical shaping should allow for a confined toroidal current of $IST=300$ kA. Hopefully Phase-2 of PROTO-SPHERA will add to the magnetic reconnection current drive, already obtained on “thin” tori, a vigorous and self-organized plasma reconnection heating: a total power of ~ 20 MW will be input into the overall plasma, while the spherical tori will fill up to 95% of the total plasma volume.

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