The PROTO-SPHERA [1] system, proposed at the ENEA Frascati research centre, is a simply connected magnetoplasma configuration, composed by a spherical torus (ST, with external diameter $2 \bullet R_{sph}$=0.7 m, with closed flux surfaces and toroidal plasma current $I_{ST} \leq 240$ kA) and by a Hydrogen plasma arc, taking the form of an electrode fed screw pinch (SP, with length $L_{Pinch} \sim 2$ m and midplane diameter $2 \bullet \rho_{Pinch} \sim 0.08$ m, with open flux surfaces and plasma electrode current I_e=60 kA), see Fig. 1a. Such a combined plasma configuration has been devised theoretically under the name "flux-core-spheromak" (FCS) [2]. The central metallic conductor of a spherical tokamak will be replaced in PROTO-SPHERA by the screw pinch acting as a plasma central column. The SP and the ST will have a common embedded magnetic separatrix: resistive instabilities will drive magnetic reconnections, injecting magnetic helicity, poloidal flux and plasma current from the electrode-driven SP into the ST and converting into plasma kinetic energy a fraction of the injected magnetic energy. The SP will be magnetically given a disk-shape near each electrode (see Fig. 1b), with singular magnetic X-points on the symmetry axis.

The first goal of the PROTO-SPHERA experiment will be to compress the ST to the lowest possible aspect ratio (A=1.2÷1.3), in a time of about 1800 Alfvén times ($1800 \bullet \tau_A \approx 1$ ms). The second goal will be to show that efficient helicity injection can sustain the ST around the SP for at least one resistive time ($\tau_R \approx 70$ ms). The third (and final) goal is to compare the ST energy confinement time τ_E with the one obtained in similar-sized conventional Spherical Tokamak experiments (with metallic center column) like START [3].

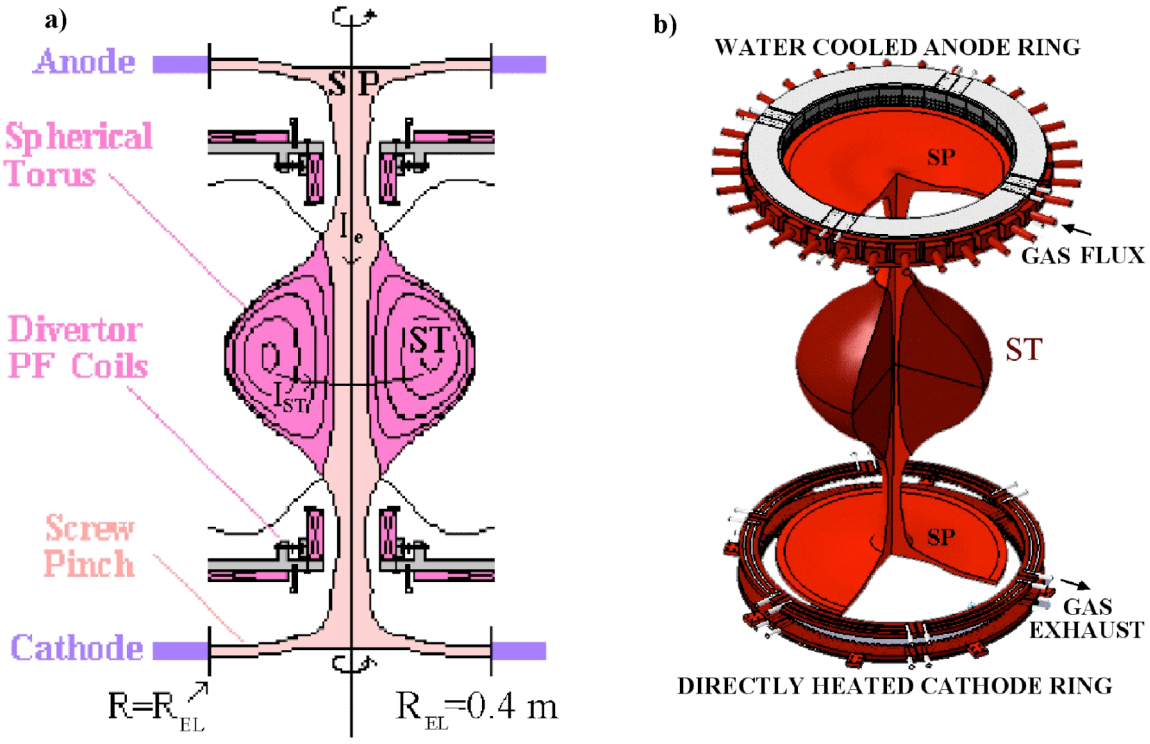

Fig. 1. a) Sketch of the PROTO-SPHERA system; b) Cut-out sketch of plasma and electrodes.

The MULTI-PINCH experiment (see Fig. 2b) is being built as an initial partial set-up of PROTO-SPHERA, devoted to assess and clarify the most critical points of the PROTO-SPHERA experiment from the SP point of view: to explore the breakdown conditions and the pinch stability in the starting phase of the PROTO-SPHERA discharge, in presence of the poloidal field (PF) shaping coils alone (see

Fig. 2a) and therefore in absence of the spherical torus. The major concern is the possibility that the pinch discharge sticks on the anode surface in some specific toroidal position (arc-anchoring).

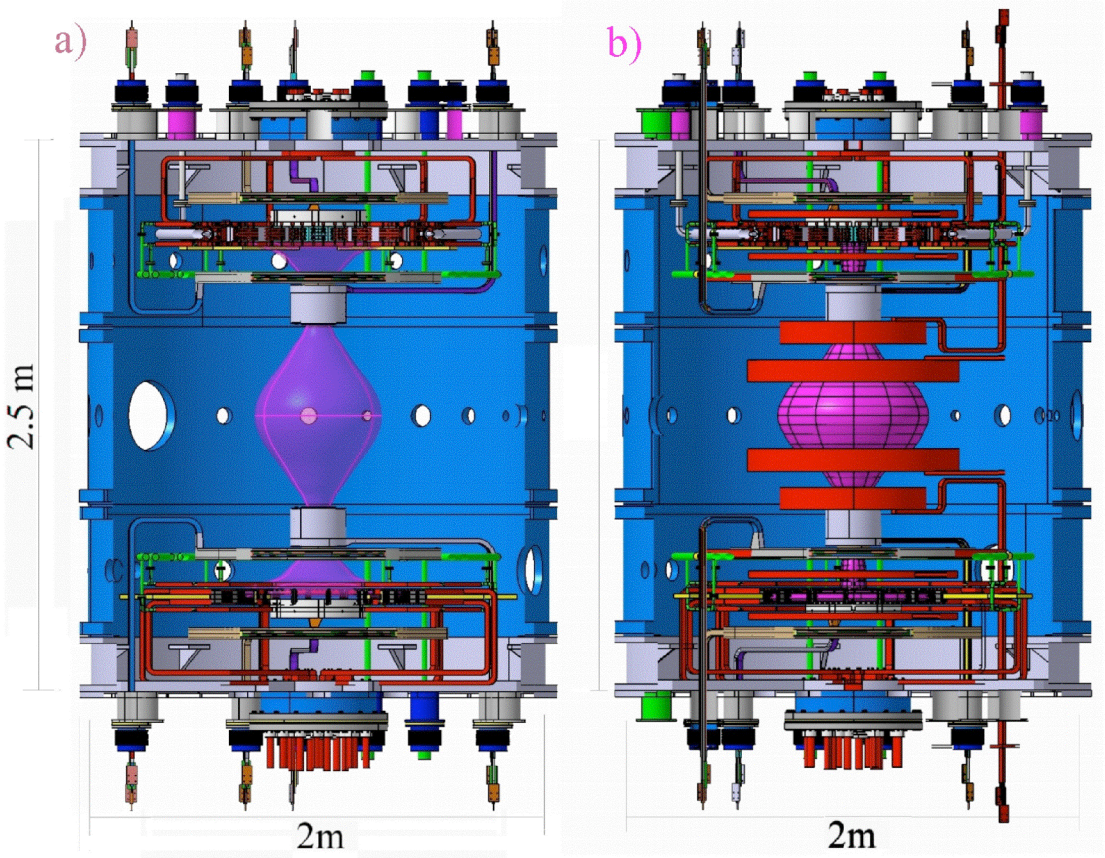

Fig. 2. a) MULTI-PINCH; b) PROTO-SPHERA, obtained adding the PF compression coils.

As a sign of international support for this project, a collaboration in the field of spherical tokamaks has been established with the UKAEA-Culham British Association. ENEA Frascati has been contributing with personnel to the MAST experiment in Culham in the three years 2004, 2005 and 2006. UKAEA Culham has donated in 2004 to Frascati the available START equipment (in particular the vacuum vessel), see Fig. 3. Further contributions from UKAEA-Culham can be expected during the final construction phases, commissioning and operation of MULTI-PINCH, with respect to diagnostics and manpower.

Fig. 3. May 2004: the transfer of the START experiment from Culham (a) to Frascati (b) and during the dismantling for recovering the vacuum vessel for MULTI-PINCH (c).

MULTI-PINCH will produce a stable screw pinch with current $I_e \leq 8.5$ kA, namely the one expected in PROTO-SPHERA before the ST formation. The four pairs of PF shaping coils will be fully recovered for PROTO-SPHERA. In the year 2005 the constructive design of the PF shaping coils has been completed with ASG Superconductors (Genova, Italy) and at the beginning of 2006 their construction has started. The construction of the coils has ended in March 2007 (see Figs. 4-5).

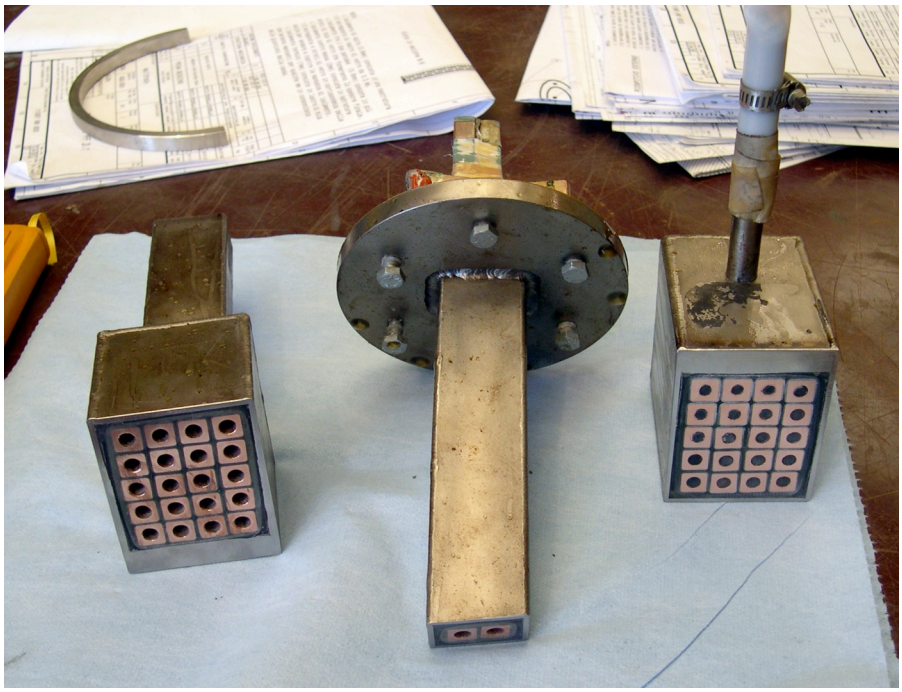

Fig. 4. October 2006: preliminary proofs for the construction of the MULTI-PINCH PF coils.

Fig. 5. March 2007: the 4 pairs of MULTI-PINCH PF coils as built by ASG Superconductors.

An European Call for Tender for the construction for the remaining parts of the MULTI-PINCH load assembly has been started in spring 2007. Examples of the detailed drawings for the MULTI-PINCH load assembly are given in Figs. 6-8.

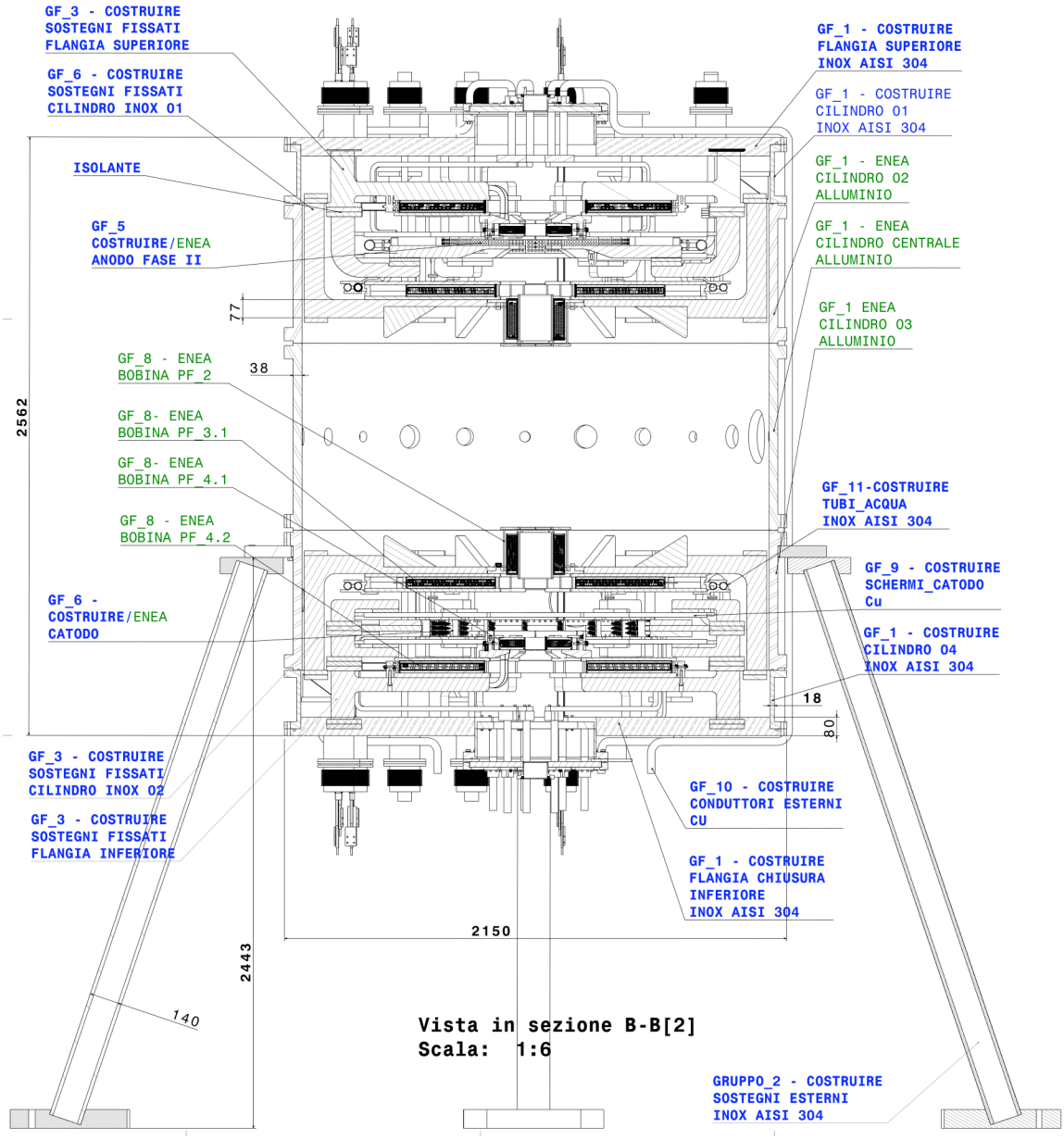

Fig. 6. 2D section of the MULTI-PINCH load assembly.

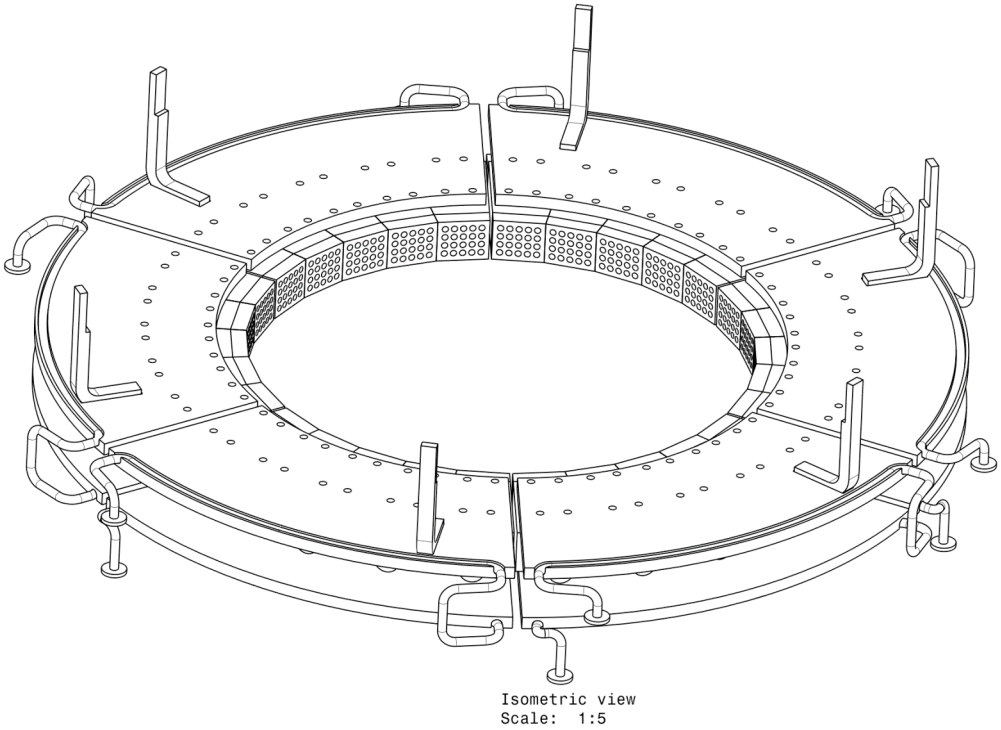

Fig. 7. Isometric view of the MULTI-PINCH anode.

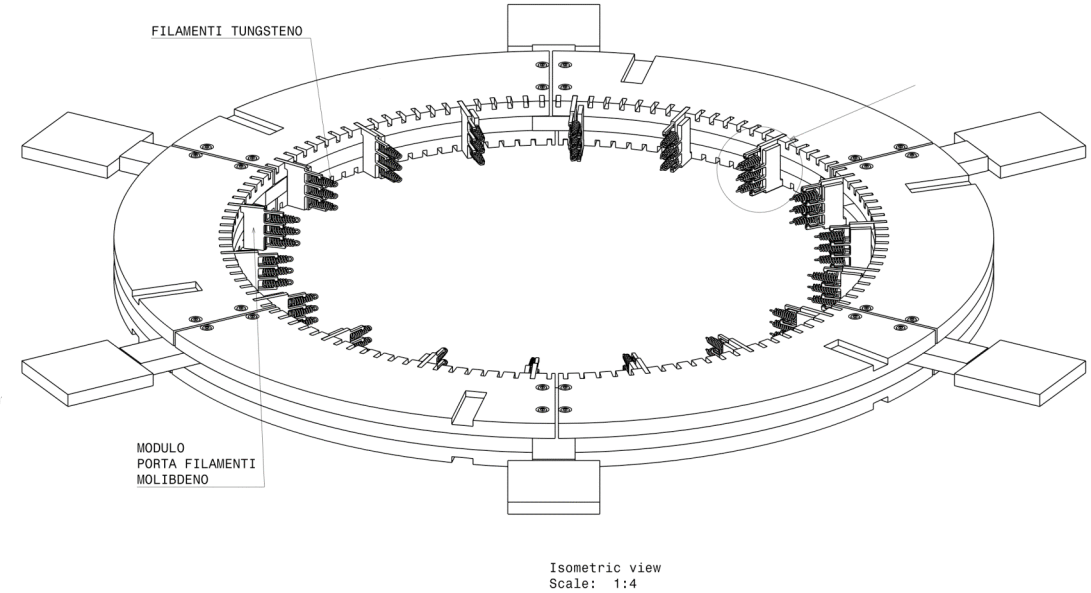

Fig. 8. Isometric view of the MULTI-PINCH cathode.

The power supplies have been defined and their procurement should be such as to have the machine ready for operation in 2009.

In case of positive results with the MULTI-PINCH experiment, the PROTO-SPHERA set-up can be completed by adding the ST compression coils (see Fig. 2b), along with an improved power supply, able to rise the pinch electrode current from $I_e \leq 8.5$ kA to $I_e = 60$ kA in ~ 1 ms.

[1] Alladio F. *et al,* 2006 *Nucl. Fusion* **46** S613
[2] Taylor J.B. and Turner M.F., 1989 *Nucl. Fusion* **29** 219
[3] Sykes A. *et al,* 1992 *Nucl. Fusion* **32** 694