Status and future plans of PROTO-SPHERA

*F. Alladio, A. Mancuso, P. Micozzi, S. Papastergiou, F. Rogier**

Associazione Euratom-ENEA sulla Fusione, CR Frascati C.P. 65, Rome, Italy

**ONERA-CERT / DTIM / M2SN 2, av. Edouard Belin - BP 4025 – 31055, Toulouse, France*

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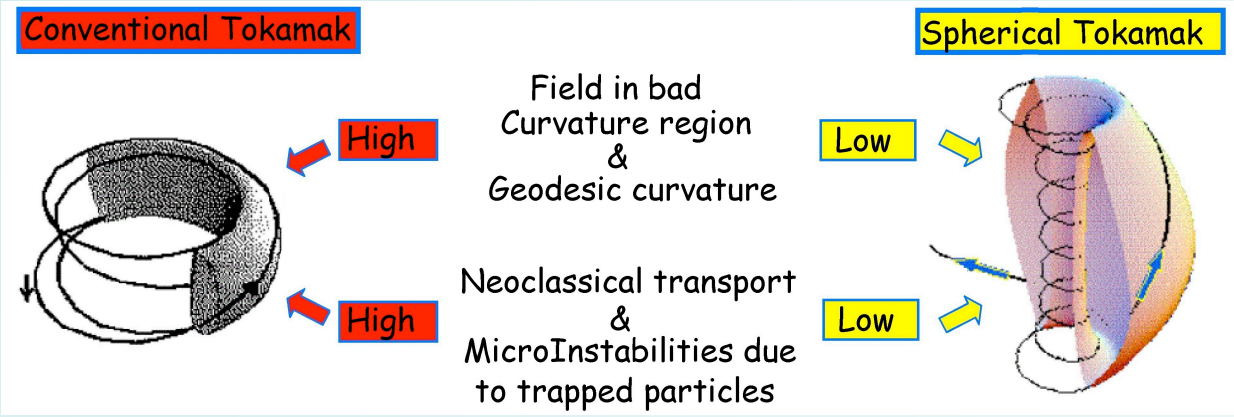
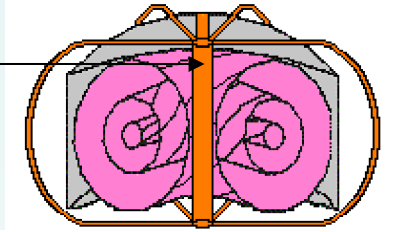
The Spherical Tokamak (ST) is a magnetic confinement configuration that provides plasma b much higher than conventional tokamaks

The advantage stems from the nearly-geodesic lines of force in ST



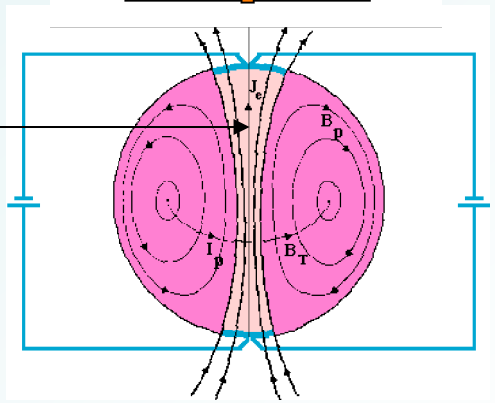
Severe space constraints for material center column:

- No space for central solenoid
- No neutrons shield (no superconductor/high dissipation)



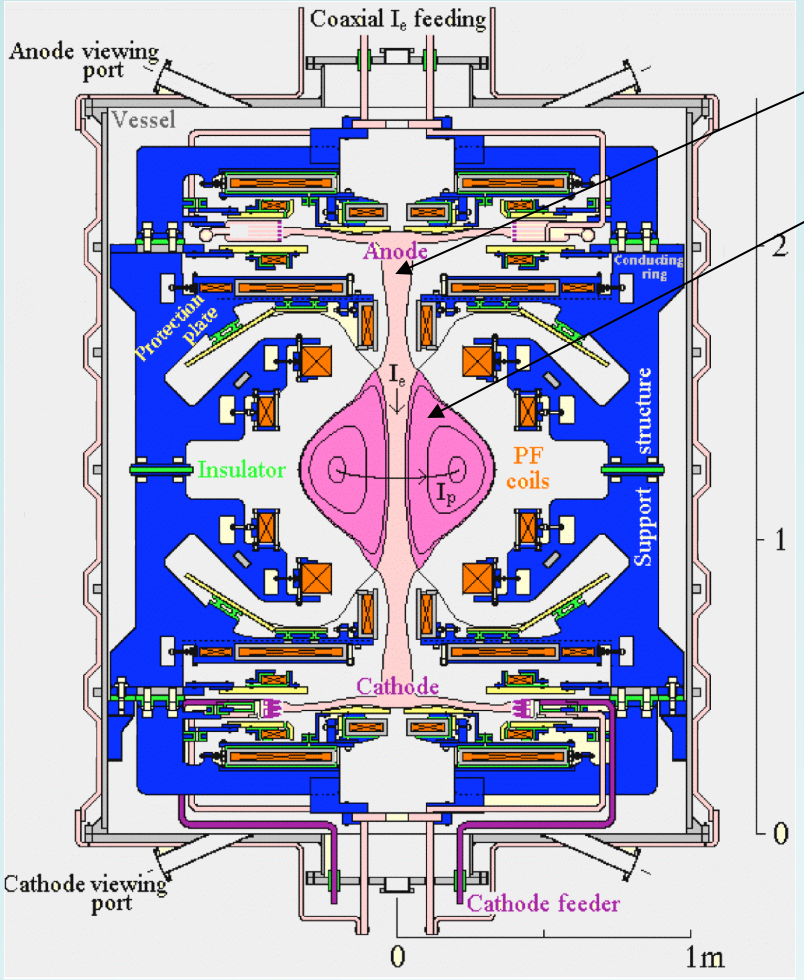
PROTO-SPHERA[1]: a plasma central column (ST-PCC)[2]

Requires electrodes and plasma self-organization!



[1] F. Alladio, et al., **Nucl.Fus. 46** S613 (2006)

[2] S.C. Hsu & X.Z. Tang, **J.Fus.En.** (2006) **Complementary proposal-LANL**



PROTO-SPHERA

PCC - ScrewPinchPlasma (SP), electrode-driven

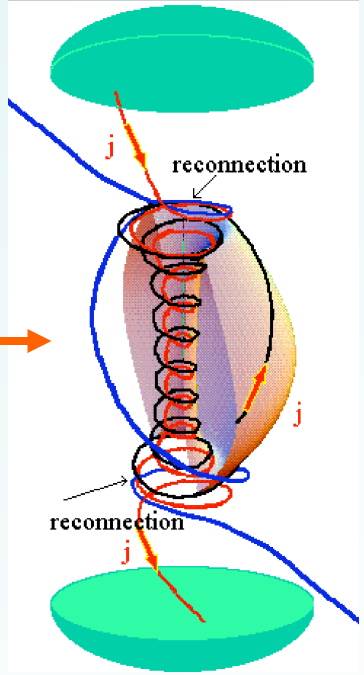
Elongated ST ($k \geq 2.3$)
to get an MHD safety factor $q_0 \sim 1$, $q_{edge} \sim 3$

PCC electrode current	I_e=60 kA
ST toroidal current (limited by ideal MHD)	I_{ST}=240 kA
ST diameter	R_{sph}=0.7 m

Driven relaxation of Plasma Central Column forms[3] & sustains the ST

[3] N. Amemiya, et al., **JPSJ 63**, 1552 (1993)

"Smoke-ring like self-organization": sustainement by Helicity Injection



Scientific Issues:

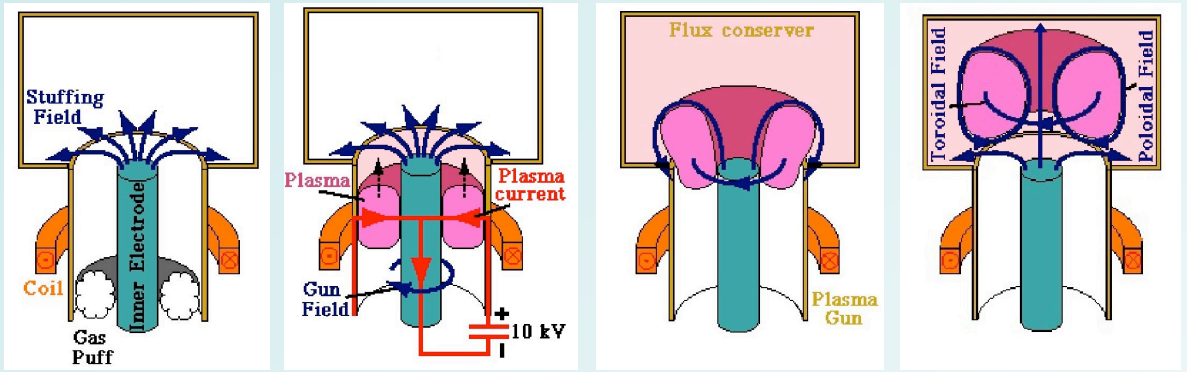
- I_{ST}= 240 kA (4xI_e) really achievable? (MHD calculation ⚿ Yes!)
- Can it be sustained for $t_R \sim$ 70 ms?
- Resistive MHD stability & confinement?

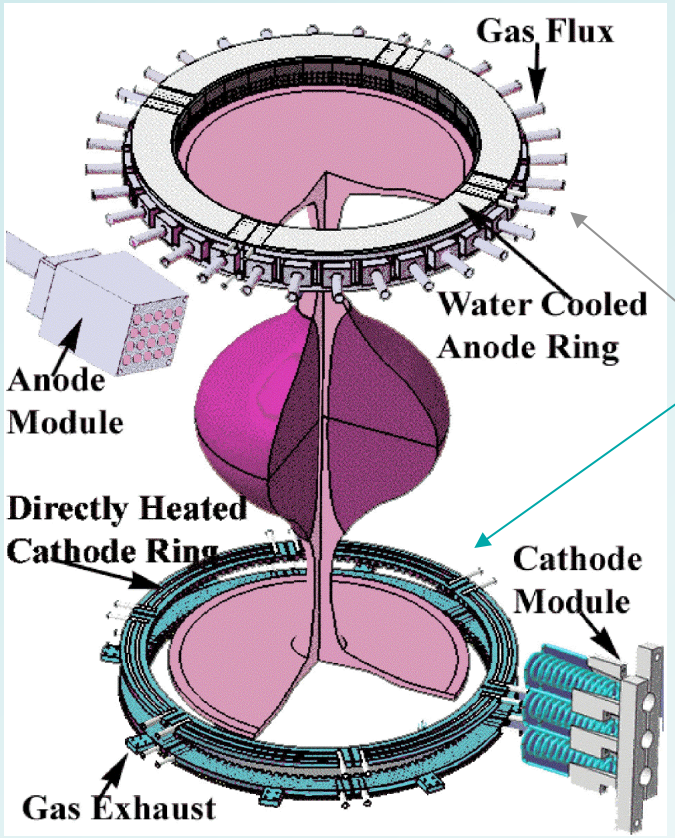
Plasma Central Column (PCC)

FLUX-CORE-SPHEROMAKS

- injected by plasma guns,
- ~10 kV voltage on electrodes
- high pressure prefilling

have MHD safety factor $q \leq 1$





PROTO-SPHERA instead

- formed via driven relaxation of PCC
- ~100 V voltage on electrodes
- tokamak-like density

Emissive modular annular electrodes:

- gas puffed hollow anode
- directly heated cathode W

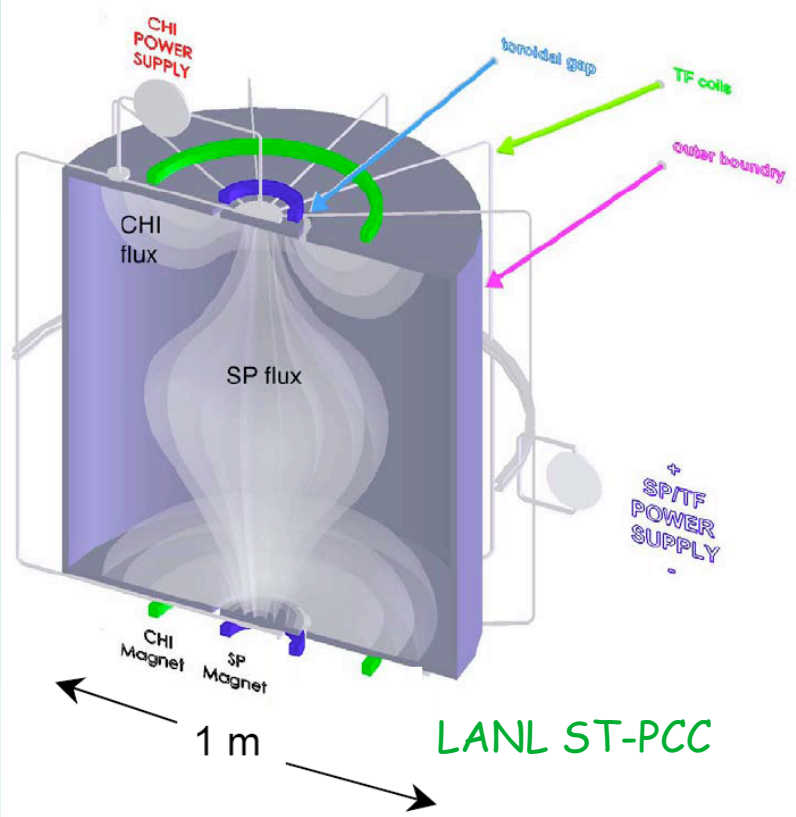
PCC disc-shaped, at interface:

- plasma current density j_e=1 MA/m^2
- power density P_e=20÷30 MW/m^2

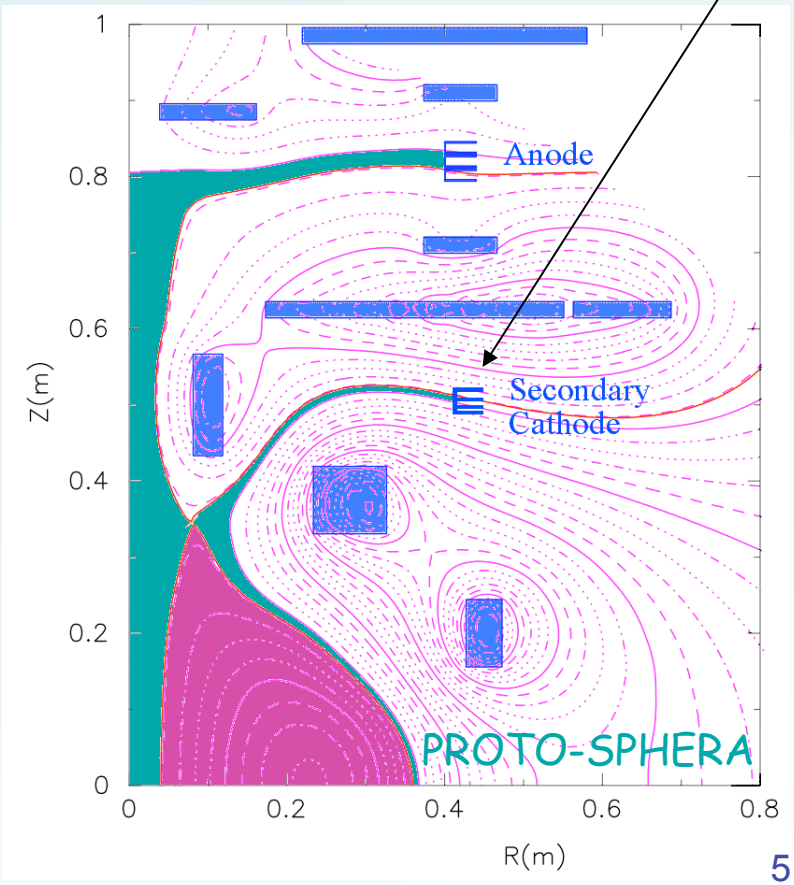
obtained on (axial) electrode modules for >thousand-1s discharges on PROTO-PINCH testbench (2000)

Comparison with the LANL proposal

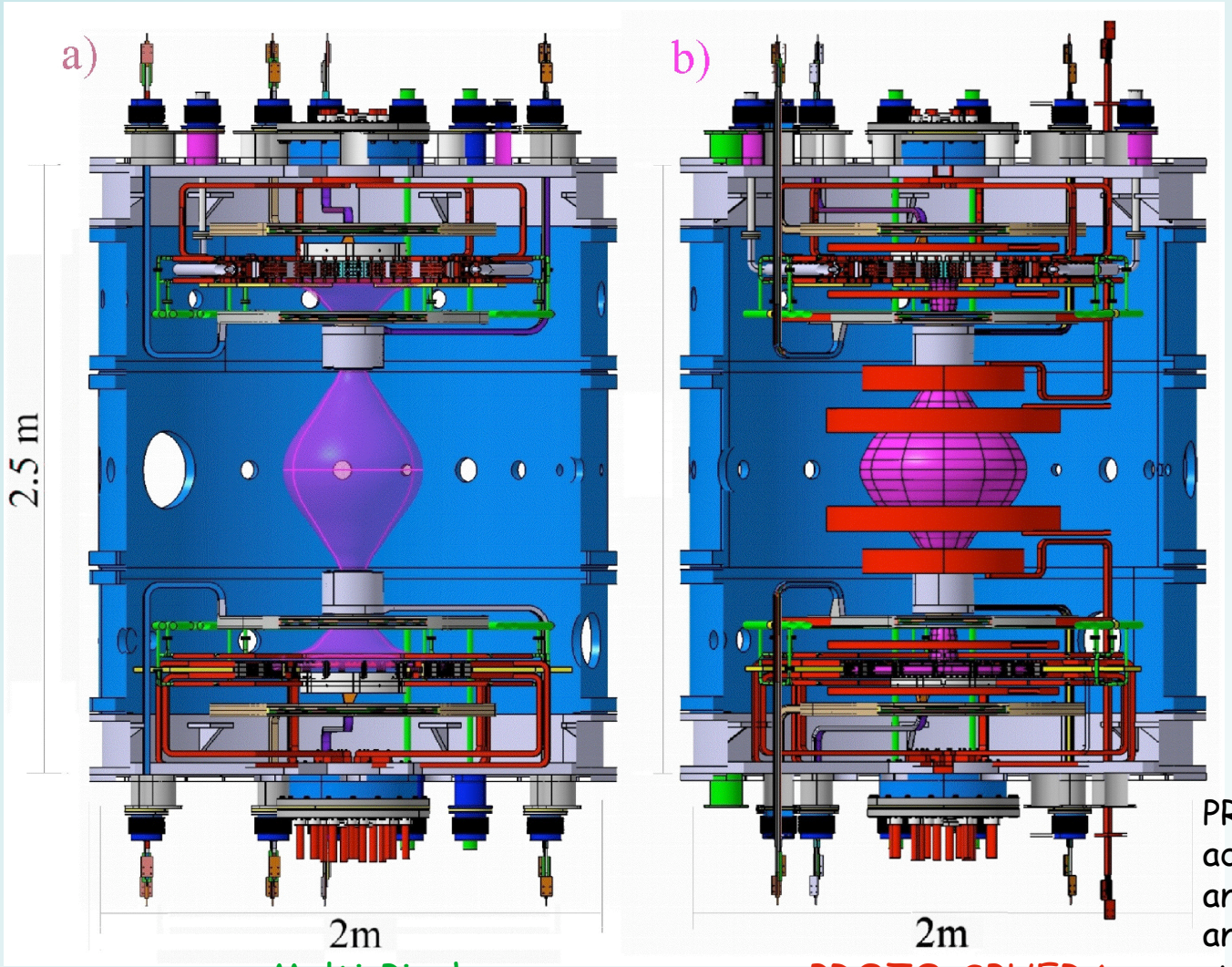
- "Proof of Principle" size
- Based on a lower order Chandrasekhar-Kendall force-free solution
- Simpler electrodes (not emissive, no shaping)
- Almost fully relaxed equilibrium
- Formed by kink instability + CHI
- Sustained by H.I. from PCC + CHI



- "Concept Exploration" size
- Based on a higher order Chandrasekhar-Kendall-Furth force-free solution
- Emissive and shaped electrodes
- Less relaxed equilibrium
- Formed by kink instability
- Sustained by H.I. from PCC alone (CHI as option)



A reduced setup (a) of PROTO-SPHERA (b) is being built inside START vacuum vessel (gifted by Culham UKAEA Science Centre) **to clarify PCC breakdown & stability with annular electrodes** (beware anode anchoring!)

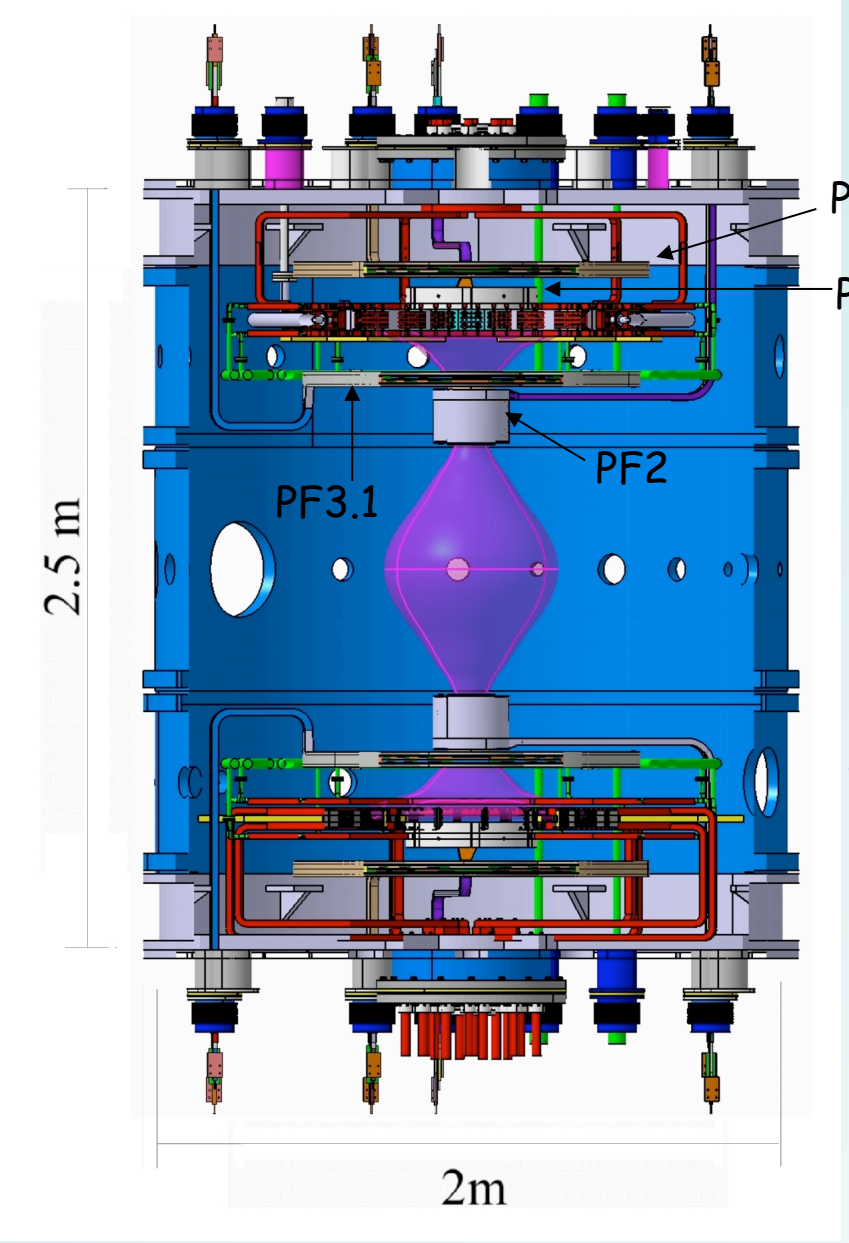


Multi-Pinch

PROTO-SPHERA

PROTO-SPHERA obtained later, adding PF compression coils and their power supplies, and implementing the PCC power supply

Multi-Pinch Experiment



Aims:
stable PROTO-SPHERA Screw Pinch plasma with full dimension, disk shape, and current $I_e = 8.5$ kA

Philosophy:

almost all parts should be reutilized in PROTO-SPHERA

START vacuum vessel
(in Frascati since May 2004)

- Partial PF coils system (constant current):
only the "Pinch shaping coils"

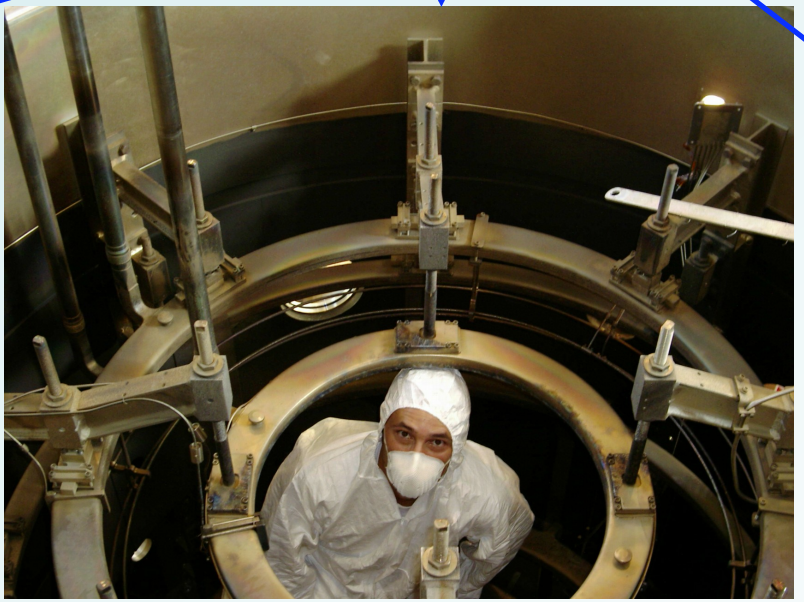
- Definitive Anode & Cathode

Progress of the Multi-Pinch construction

START in Frascati

Arrival
May 2004

Disassembling
October 2004



Progress of the Multi-Pinch construction

PF coils have been built by ASG Superconductors S.p.A. (Genova, Italy)

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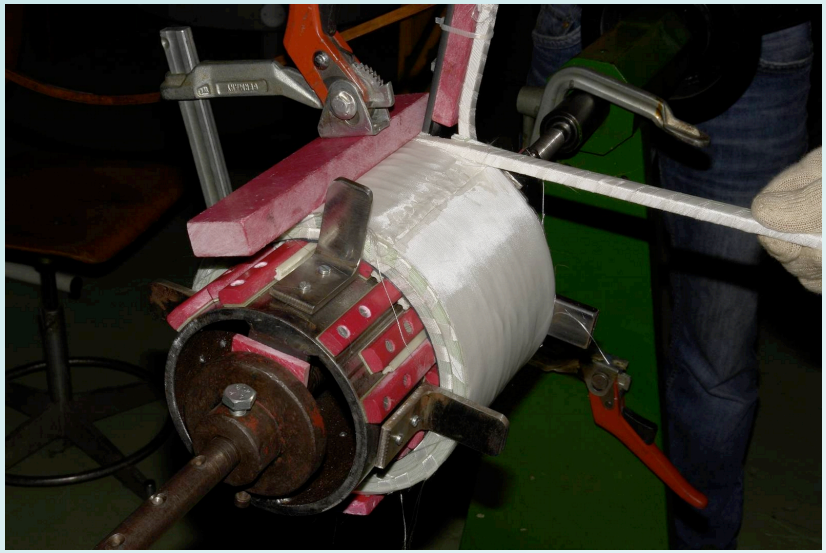

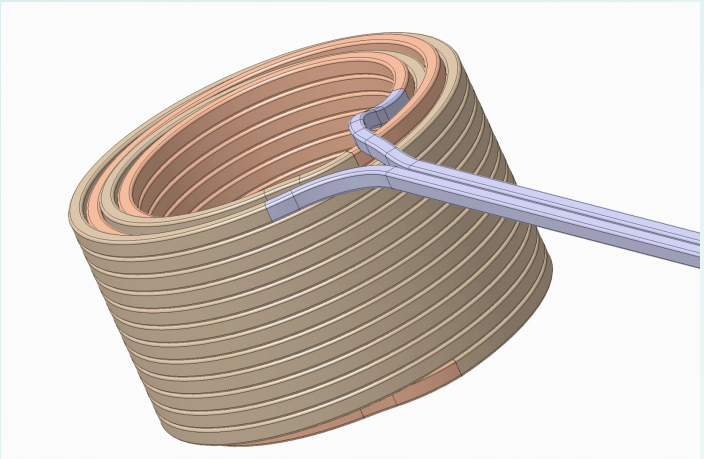

PF2: Pinch "mirror coil"

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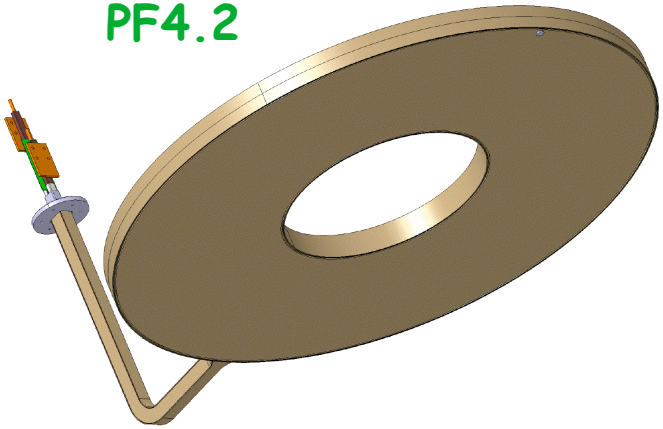
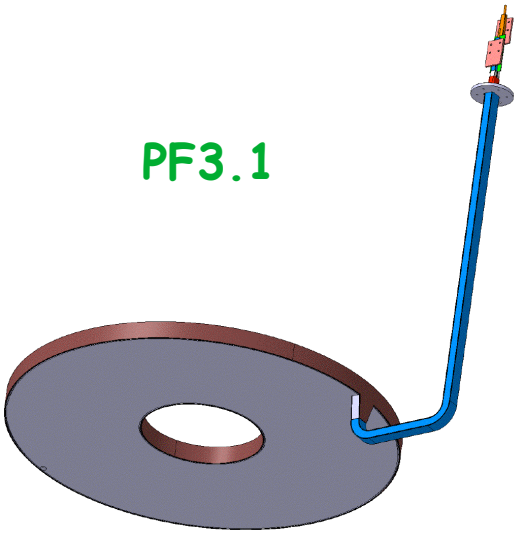
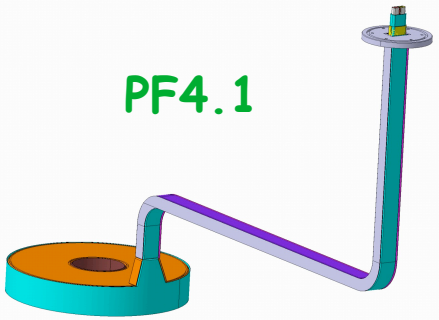
PF4.2



PF3.1

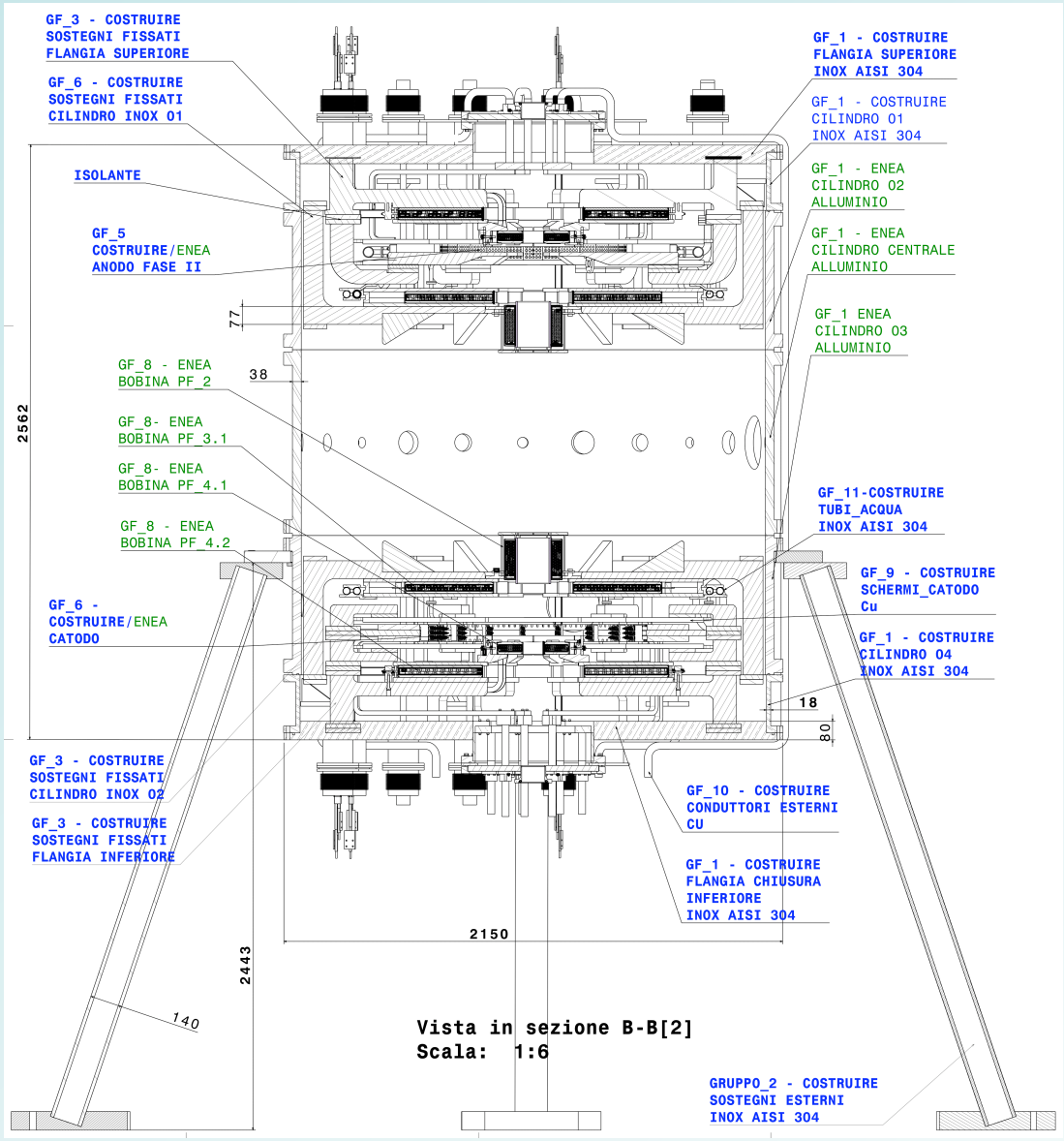


PF4.1

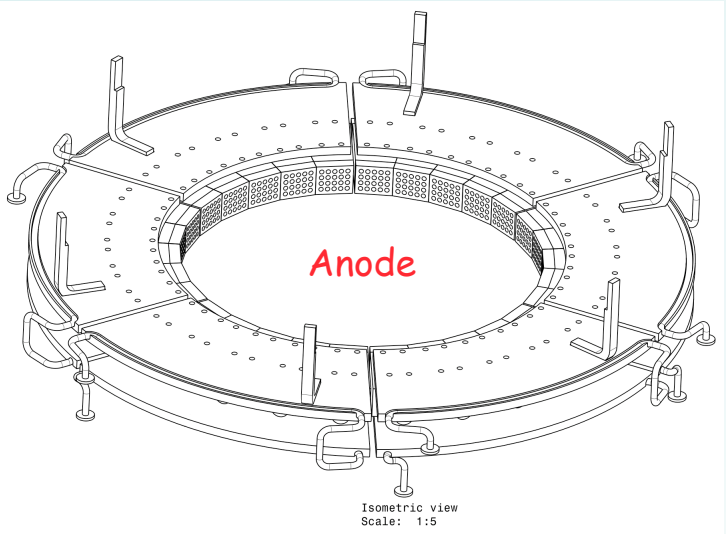


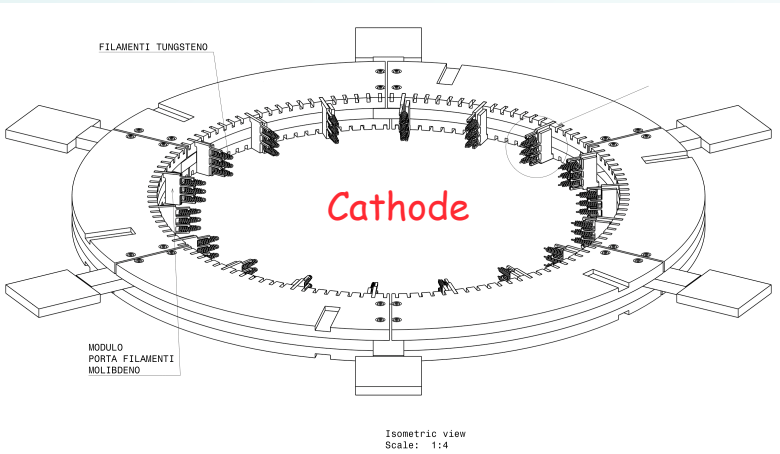
Pinch "shaping coils" (pancake kind)

Progress of the Multi-Pinch construction



European "call for tender" to build the *Load Assembly* **has been started**





Actions & Time Schedule

- **Power Supplies**: PF coils, Cathode and Screw Pinch (reduced)
- **Diagnostics**: Spectroscopy, Magnetics*, Fast Camera*
- **Vacuum System**, **Data Acquisition System** and **Control System**

Realistically the first Multi-Pinch plasma could be obtained at the end of 2009

* *Culham collaboration?*