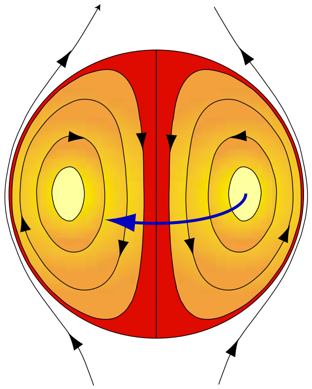
What is a spheromak?

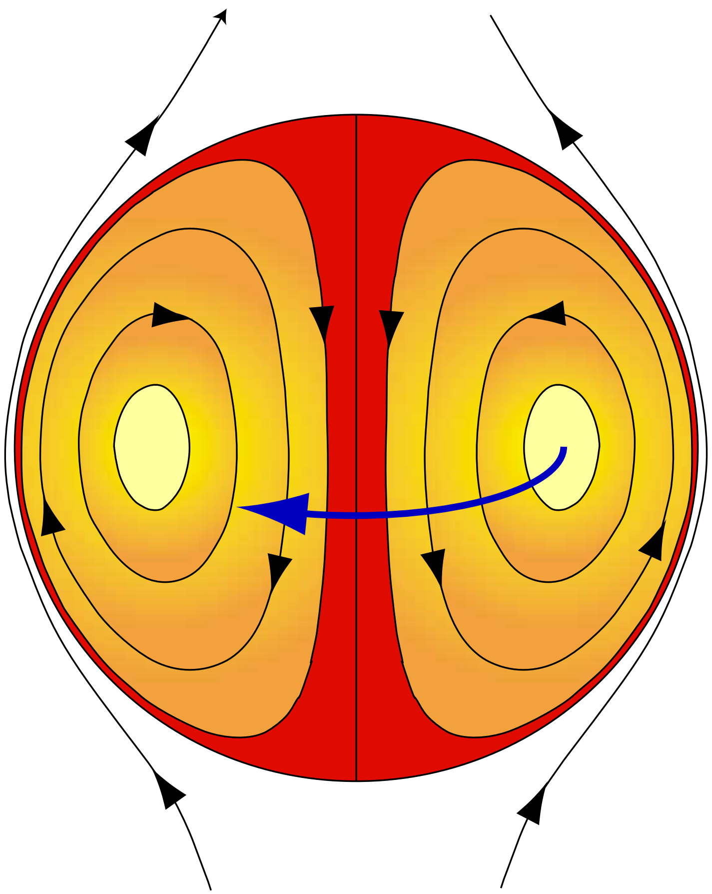


A spheromak plasma

A spheromak device

- The term spheromak has two meanings to fusion scientists:
  1. a spherical plasma confined by magnetic fields generated by electrical current flowing within the plasma
  2. the device used to form and contain spheromak plasmas
- Spheromaks are interesting to study because they might prove to be useful for producing fusion energy and because the physics which governs their behavior is common to space plasmas like the solar corona or the earth's magnetosphere.

Essential Characteristics of a Spheromak Plasma



Arrows indicate flow of current and direction of magnetic field lines.

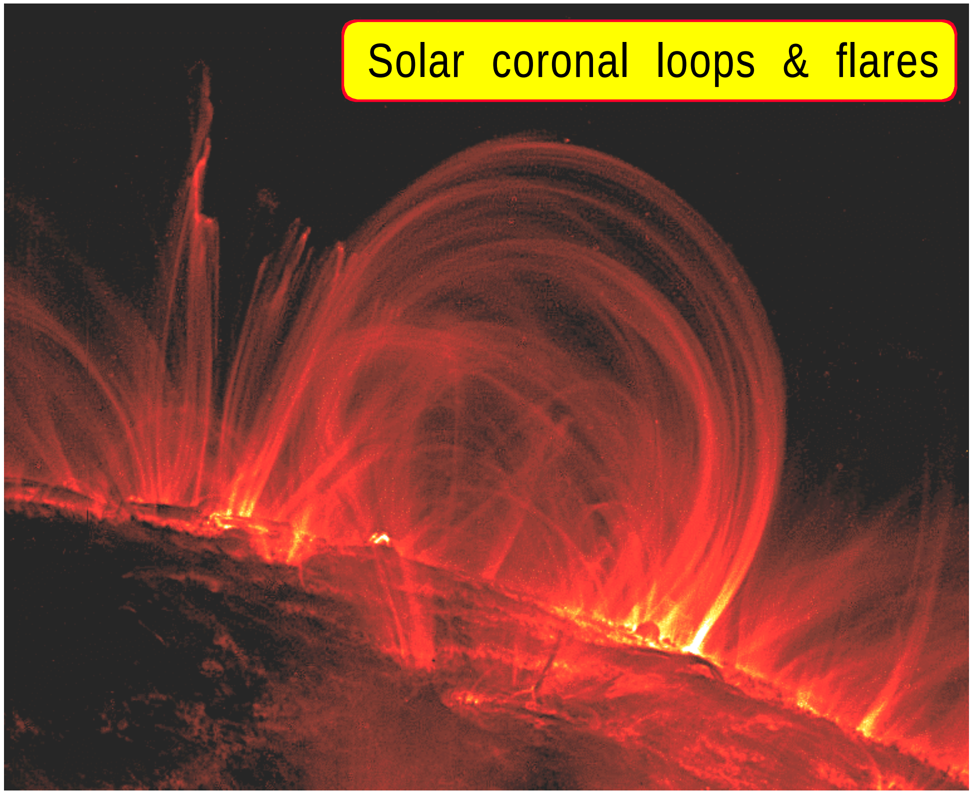
- Low-aspect-ratio (R/a) toroidal (donut-like) magnetic configuration.
- Confining magnetic fields produced by currents in the plasma itself.
- Nearly force-free field aligned currents:

$$\lambda = \frac{\mu_0 j}{B} \qquad \nabla \times \vec{B} = \lambda \vec{B}$$

- Magnetic topology:
  - — edge: Poloidal fields & currents
  - — core: Toroidal fields & currents

The physics free-flowing plasma currents that governs spheromak behavior is common to many other situations.

In the spheromak, free-flowing currents determine the essential properties of the plasma such as magnetic field topology, pressure, and temperature.



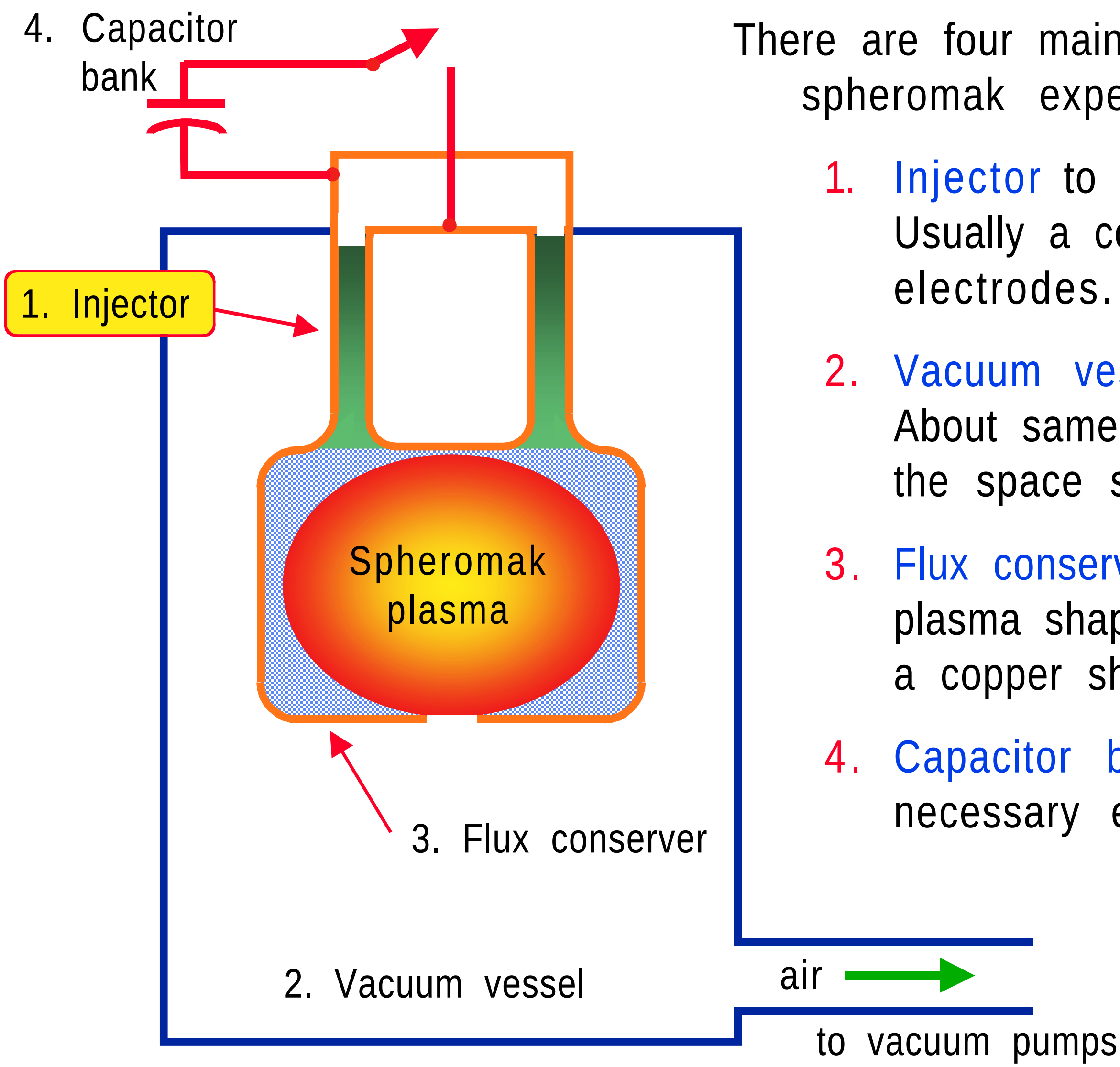
This is also true for

— solar corona
— interplanetary solar wind
— galactic magnetic fields
— other fusion devices

3-d numerical simulation can give us clues to how such systems operate, but computational limits and limited physics content lead to large uncertainties.

Detailed measurements in actual plasmas will yield better understanding and improved models.

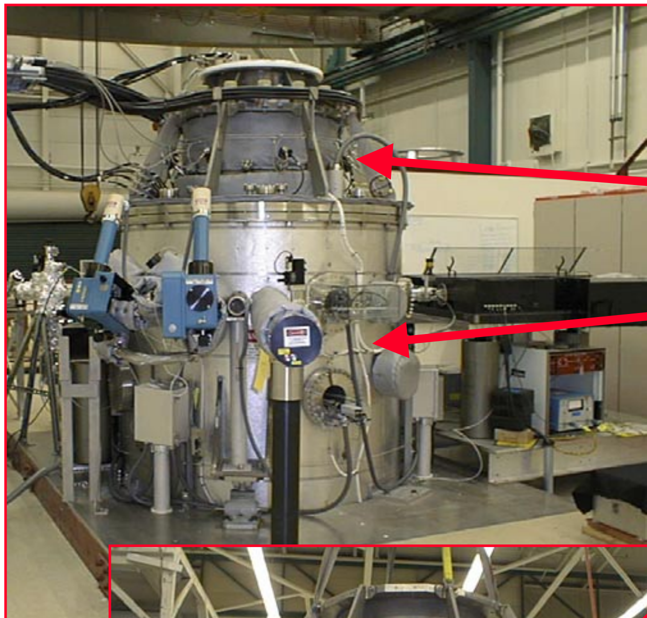
Parts of a spheromak experiment



There are four main parts to present-day spheromak experiments

1. Injector to create the plasma. Usually a coaxial region with two electrodes.
2. Vacuum vessel to keep out air. About same vacuum as surrounds the space station.
3. Flux conserver to maintain the plasma shape and position. Usually a copper shell.
4. Capacitor banks to drive the necessary electrical currents.

Photos of the SSPX Spheromak Experiment



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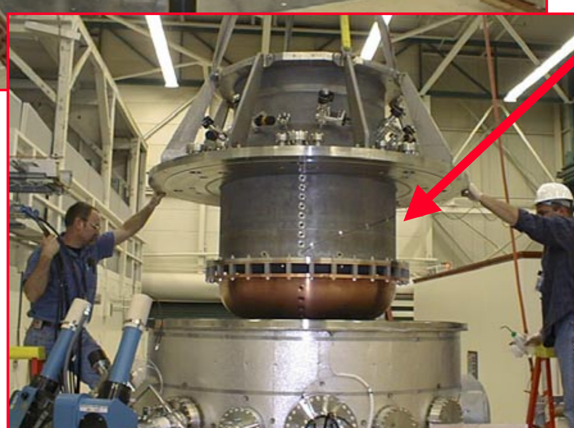
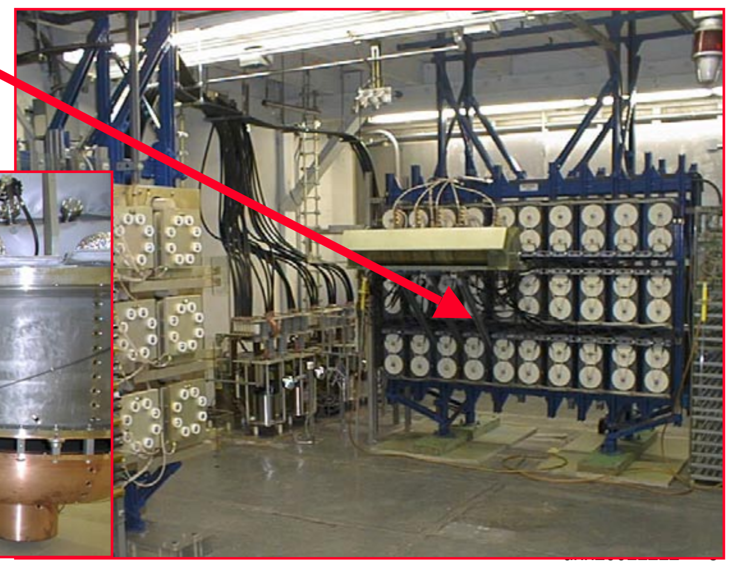
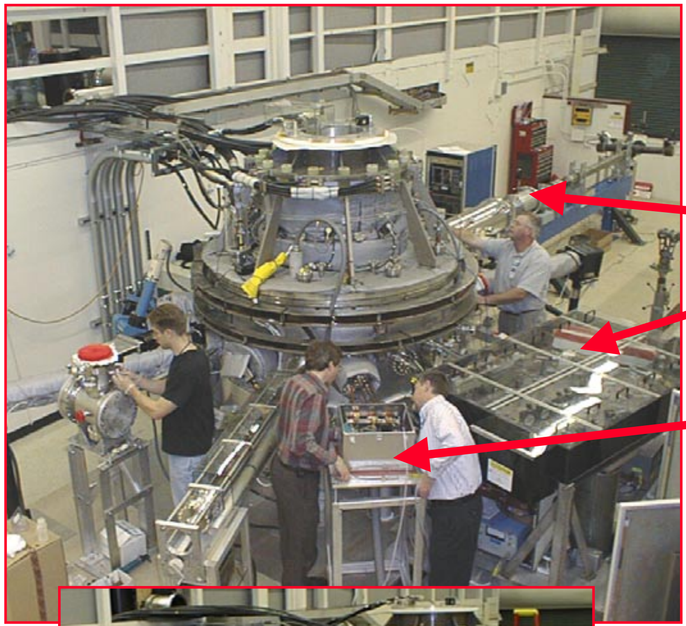




Photos of the SSPX Spheromak Experiment



All together, the SSPX spheromak is a complex device.

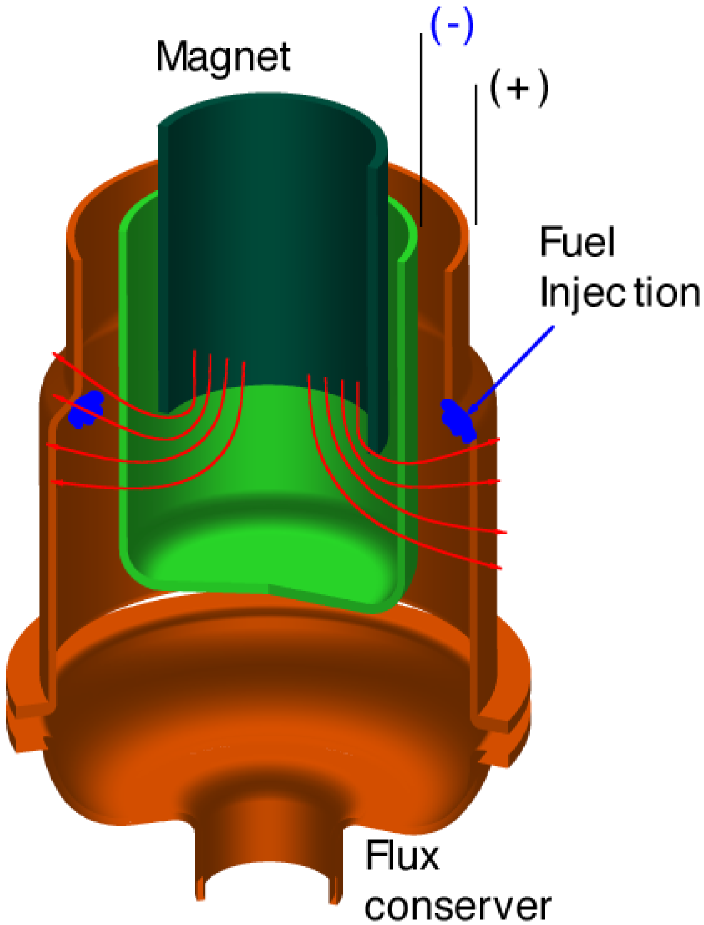
In addition to the basic parts of the spheromak, many scientific instruments surround the vacuum vessel to measure the properties of the spheromak plasma inside.

These instruments are designed, built, and operated by a team of students and scientists working to develop fusion energy.

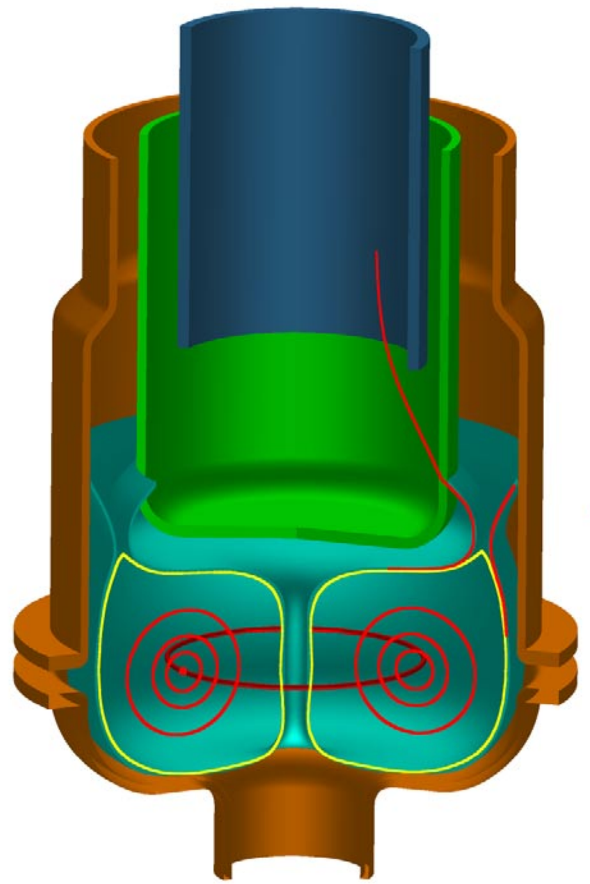
A computer control system monitors the operation of SSPX and stores the data acquired by the many diagnostic instruments.

Spheromak plasmas formed using coaxial injection

Initial Vacuum Fields

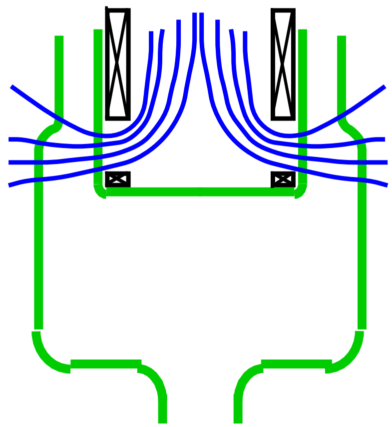


Fully-formed spheromak

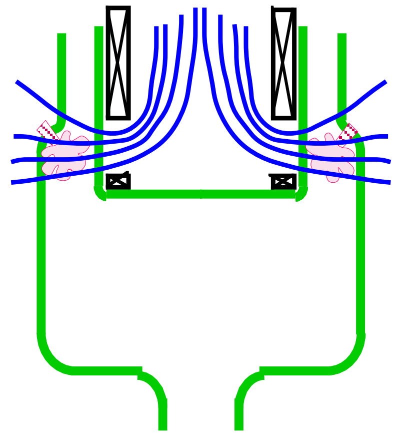


Typical spheromak formation sequence

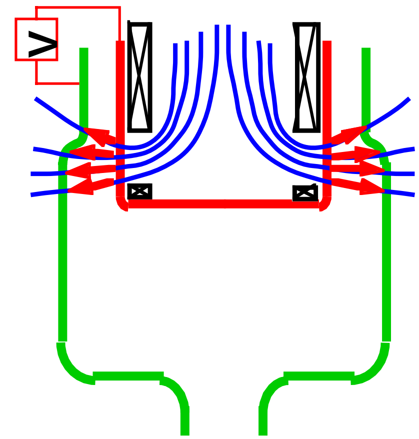
1. Magnetic field



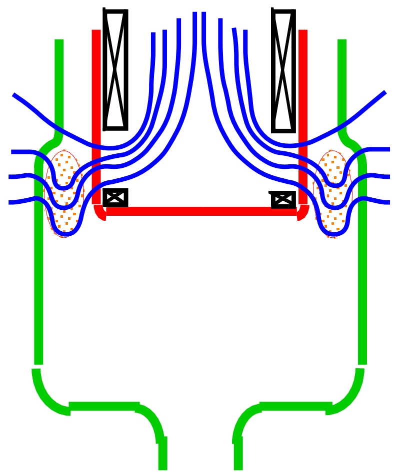
2. Puff hydrogen



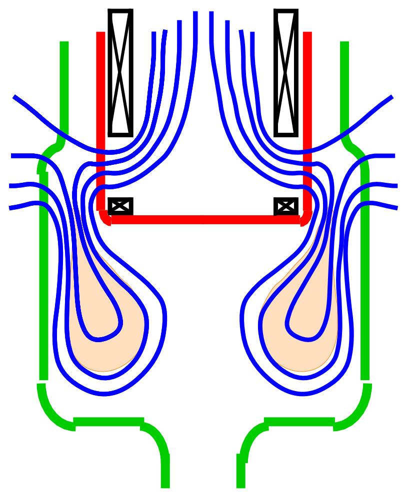
3. Apply high voltage



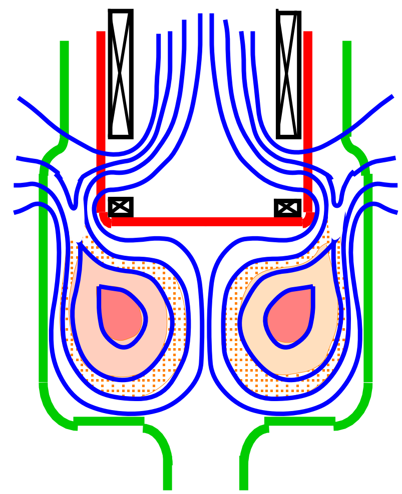
4. Plasma acceleration



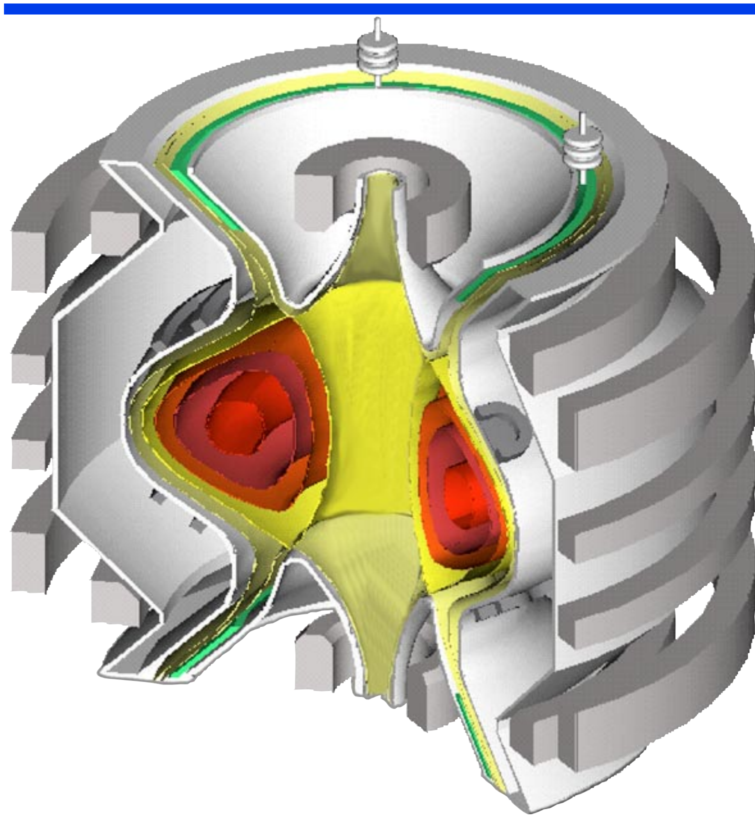
5. Plasma expansion



6. Sustained spheromak



The Spheromak offers a potentially attractive reactor concept and is rich in physics content



Artist's concept of a spheromak fusion reactor. About 6m in diameter and 6m tall for a 1000MW unit.

- Simple coil geometry
  - self generated confining fields eliminate need for most complex and massive coils
- Compact
  - possibly 1/10 the size of comparable tokamak
- Steady state
  - plasma dynamo transfers external voltages to the interior