NEUTRAL BEAM TEST FACILITY

PRIMA project

"The two prototypes SPIDER & MITICA will have performance never before reached"

Mainly the structures , being realization in Padua, that will host the new plant of the development and the test of the neutral injection system for plasma heating of ITER, the future thermonuclear fusion reactor.

The heart of the experiment consists of a particle accelerator capable of transform the hydrogen (or a substance very similar, called deuterium) in a beam of neutral particles with very high speed and, consequently, high energy.

The beam will be injected in the reactor and will collide with the fuel contained in its interior by heating up to the temperatures required to trigger fusion processes (100 million degrees), as a kind of large "lighter", without which the reaction could hardly be and remain on.

The scientific goal of the PRIMA project is to get ready a system for obtaining an atoms beam of high energy and a power of 16 megawatts, with an operation of the plant almost continuous, which served to heat the plasma in ITER.

They are performance never before achieved, hence the need to find the right place where it's possible to design, build and test a device complex as follows:

- space large enough to contain the large equipments under test;

- a power network which can provide the high power applications;

- adequate resources to create buildings and infrastructures;

- a solid organization, with a laboratory, engineers and

- physical experts, able not only to design, but also to operate the facility, assisted by a group of technicians and competent administrative.

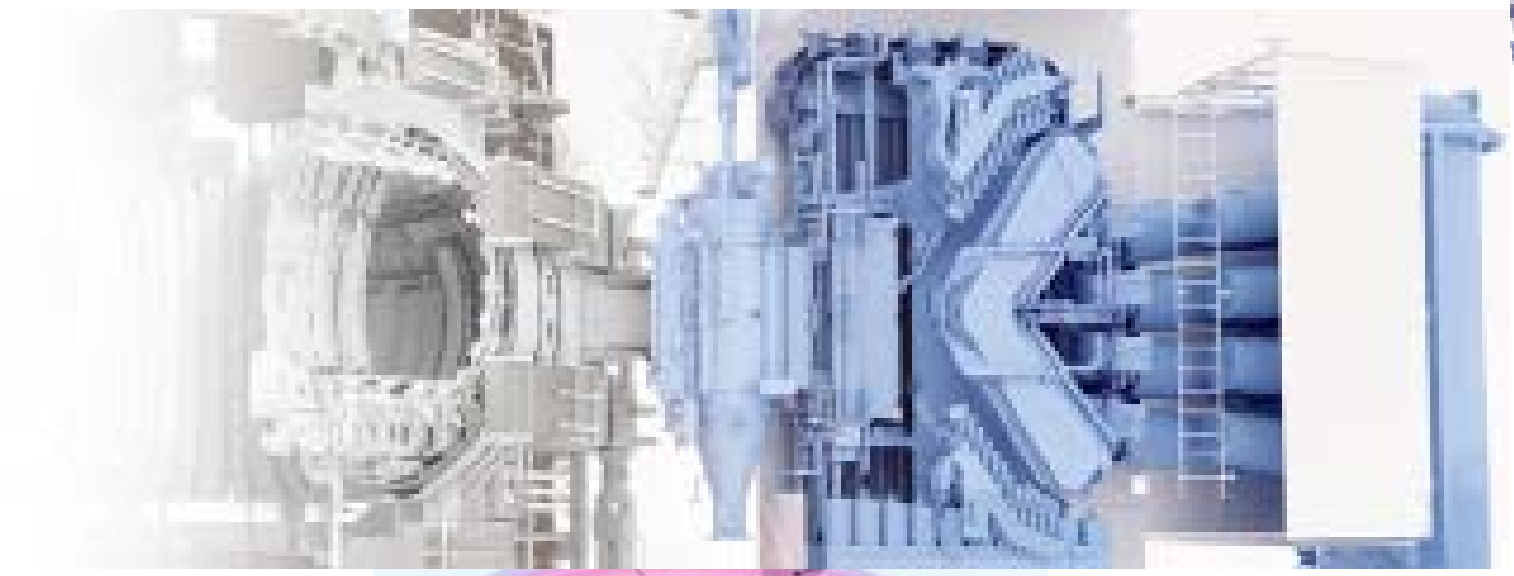
The achievements are now in course and the works already completed enabled the start of the installation of the first equipments the supply of which is entrusted to Europe and Japan, with the support of India.

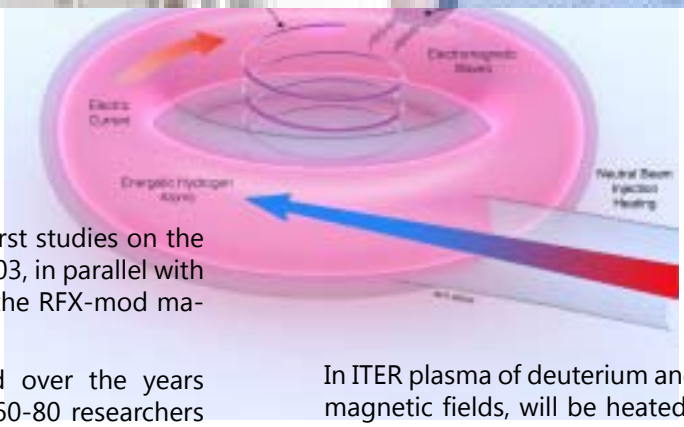
An international enterprise that projects Italy directly in the heart of the future fusion reactor.

Consorzio RFX - ENEA, CNR, INFN, Università degli Studi di Padova, Acciaierie Venete SpA

What is the NBI system?

the system of neutral injection works a bit like the steam of the coffee machine in the bar, when warms cappuccino. The beam penetrates the plasma and neutral particles begin to collide with the particles that meet initiating collisions and thereby raising the temperature for kinetic effect.





Consorzio RFX initiated the first studies on the neutral injection system in 2003, in parallel with the experimental activity on the RFX-mod machine.

The research has developed over the years leading to a team of about 60-80 researchers involved in the design of the components of the NBTF plant.

The skills in the laboratory allow, in addition to providing research infrastructure, to host, build and operate the injector, with the collaboration of European laboratories at Culham (UK), Garching (Germany), Cadarache (France) , Naka (Japan) and Bhat (India).

Consorzio RFX will be the scientific responsible of the experiment

In ITER plasma of deuterium and tritium, confined by intense magnetic fields, will be heated by radio frequency systems and by beams of neutral atoms reaching the optimal conditions to obtain the processes from fusion. The ITER project expects that the fusion power produced exceeds that fed into the system from the outside by a factor of 10.

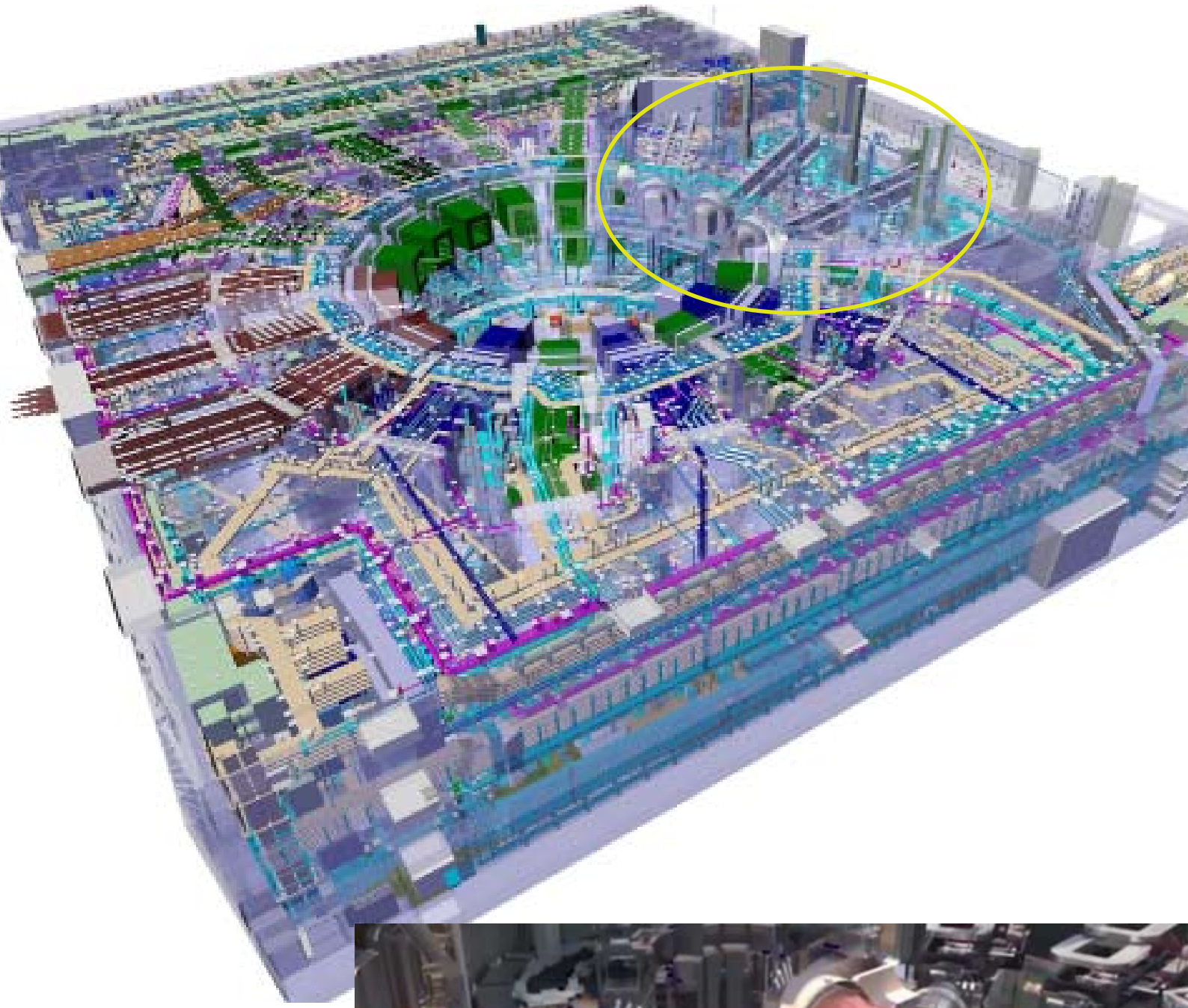
The heating by neutral beams will be realized through 3 injectors which will provide plasma total of up to 50 MW of power.

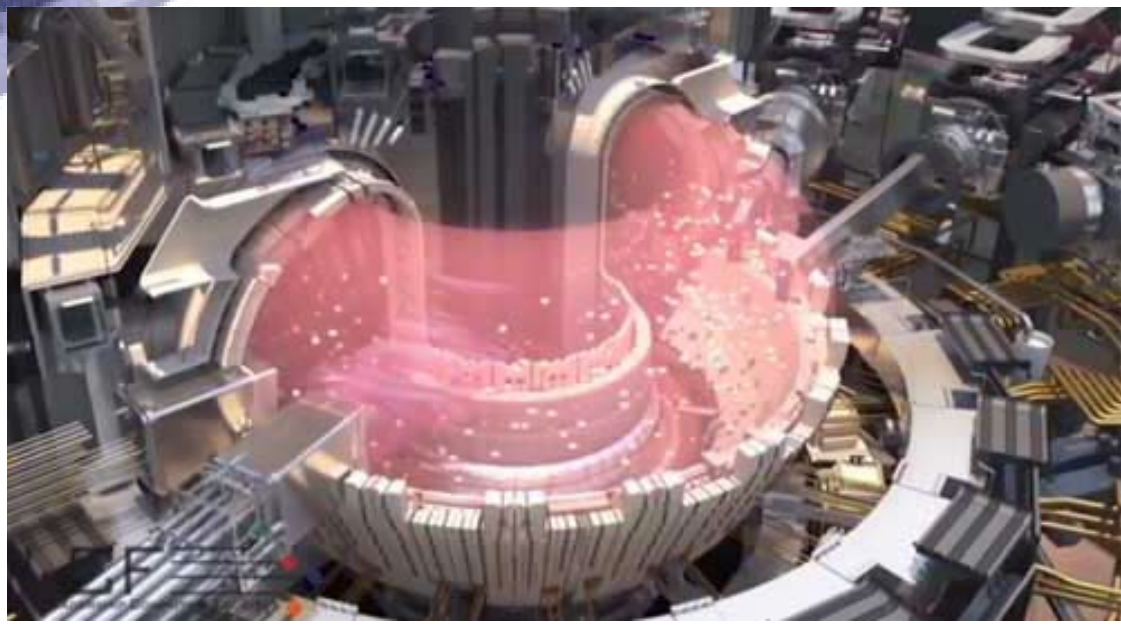
Each injector is composed of a source of negative ions (deuterium), an electrostatic accelerator, a neutralizer, a separator of residual ions and finally a calorimeter.

The accelerator will be working to 1 MW of voltage with a current at the grids up to 40 A (16 A of beam) with pulses lasting up to an hour.

In order to develop and test injectors to be installed on ITER, a laboratory in Padova (Neutral Beam Test Facility - NBTF) is being built; it is suitable to accommodate the prototype and subsequent refinements (said MITICA). The construction of NBTF began in September 2012.

Overall of the ITER plant.
On the right, in gray, the housings of the systems of neutral injection, which will be made on the basis of the results obtained in the prototype of Padua





Rendering of the interior of the ITER experimental fusion reactor, under construction in France.
Highlights, in pink, the plasma column flowing within the vacuum chamber. On the right, in gray, neutral injectors realized in the prototype of Padua.

The Italian commitment

Achieve the buildings and infrastructures of the NBTF system

Entities involved: CNR and INFN

total investment of 24 M€uro

In parallel to the construction of ITER, it has been initiated and is ongoing at the Consorzio RFX, the realization of the new international laboratory for the development of the neutral injectors, the Neutral Beam Test Facility (NBTF) - PRIMA Project.

The PRIMA Project has been approved by the ITER Council on the basis of a Memorandum of Understanding between ITER and Fusion for Energy (the European Agency of ITER) and of the NBTF Agreement between Fusion for Energy and Consorzio RFX.

In the framework of these international agreements, Italy has committed to achieving the buildings and the basic infrastructures of the new laboratory, for the commitment of Europe and ITER to provide equipment and special installations.

The Ministry of Education has entrusted the construction of buildings and infrastructure to CNR and INFN.

These RFX partners have in turn assigned to Consorzio RFX the task of creating the buildings of Test Facility for the NBI system (NBTF) at the Research Area of the CNR of Padua.

Always to Consorzio RFX, it has been entrusted by ITER, the design of all scientific components and equipments.

The Italian commitment is for the supply of:

buildings, *complete with auxiliary facilities,*
special systems, *such as system of fire detection and putting out the CED premises and medium voltage network transformers of experiment*
medium voltage network *of experiment*

Buildings:

The complex of PRIMA buildings covers a total area of about 15.500m2 of which 7400 m2 are covered, and a volume of 150.000m3.

They include 5 main warehouses and some necessary infrastructures in order to contain:

- auxiliary devices such as: the power supply of conventional medium and low voltage, buildings air treatment, security, etc,

- special devices such as systems of detection and putting off of fire in the CED and transformers premises,

- the medium voltage network of experiment.

BUILDINGS

In the photo, a view of the building that will house the control rooms of MITICA and SPIDER

On the basis of allocations by INFN and CNR of the funds provided by the Ministry of Education, Consorzio RFX has designed and contracted buildings. Work began September 7, 2012, are nearing completion, with some experimental halls already completed. It's ready to start the contract for the construction of the infrastructure of electrical connection between 400/21 kV substation at high voltage and the Facility. Remain to be made by Consorzio RFX some completion works (biological shielding furniture and related auxiliary facilities, outside sprinklers, limited additions).

INFRASTRUCTURES

Above, the North facade of the main building (Building 1), control rooms and power supplies, which will host the two experiments: SPIDER and MITICA. Additional buildings will house dedicated power supplies and other auxiliary facilities.

The photo on the right shows the inside of the building 1. In the foreground, the biological shielding (under construction) in concrete, which will contain MITICA. In the background, the shielding of SPIDER, already completed.

The shields are intended to protect against radiation and neutrons produced by accelerators. With these shields the surrounding assembly area will be fully accessible without any restrictions, even during the experiments.

The image at the bottom right shows the interior of the building 2, intended to house the cooling system of the two experiments. The room is approximately 80 m long and 20 m wide and has a extended basement to accommodate the pipelines of the refrigerant fluids.

SPIDER & MITICA
The commitment of the partners: Europe - Japan - India

Realize the componements and the scientific equipments

Investment: 200 MEuro

Two independent experiments:

MITICA scale prototype one to one of the injectors of neutral particles of ITER

SPIDER prototype of the negative ions source of ITER accelerators

Investments by F4E and other Domestic Agencies (DAs) for SPIDER & MITICA: 200 Million Euros

By now Fusion for Energy has banned European tenders for the construction of facilities dedicated to NBTF for a total amount of 43 million euros.

The contracts awarded to Italian companies amounted to 32 million euros, equal to 75% of what is allocated so far.

In the period 2012-2019, Europe contributes to operating consumptions and costs of the facility (100%), staff costs of Consorzio RFX (40%) for a total amount of 38 million euros.

Consorzio RFX provides the project team (60-80 persons FTE per year) for activities of design, of technical and scientific support to the management of the contracts, to integration activities in site that include: installation, commissioning and integrated tests of the experiments according to what foreseen by NBTF Agreement. The team will then lead the R&D activities necessary to achieve the high performance required in ITER.

Building 1

Cross-section of the main building that will house the two experiments: SPIDER, the ion source (on the left) and MITICA injector (on the right). Highlights on the top, left, the line of high voltage transmission (1 MV).

SPIDER
the ion source

The source in scale 1: 1 will be used to develop the technology for the production of negative ions.

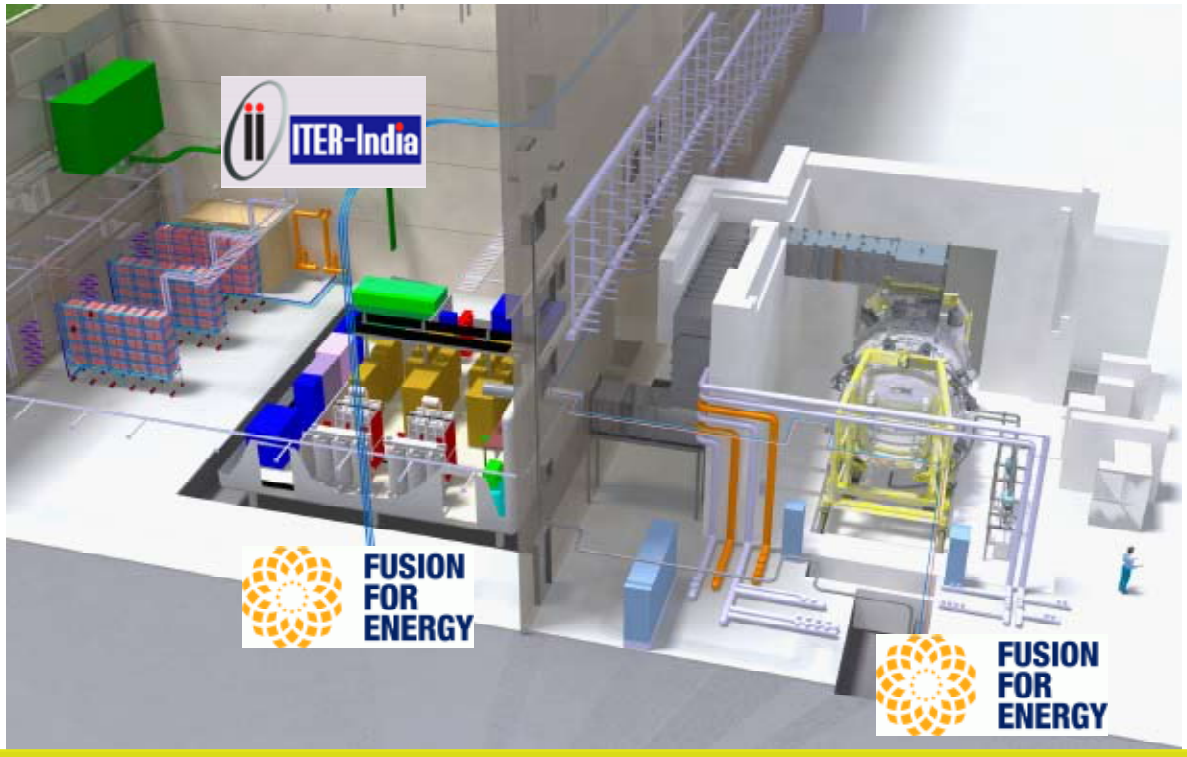
The components of SPIDER are provided by Europe and India, as appeared from the 3D representation shown in Figure.

On the right the vacuum chamber enclosing the source SPIDER; in the center the power supply room of the experiment; on the left the power supply of the grids that allow to accelerate ions.

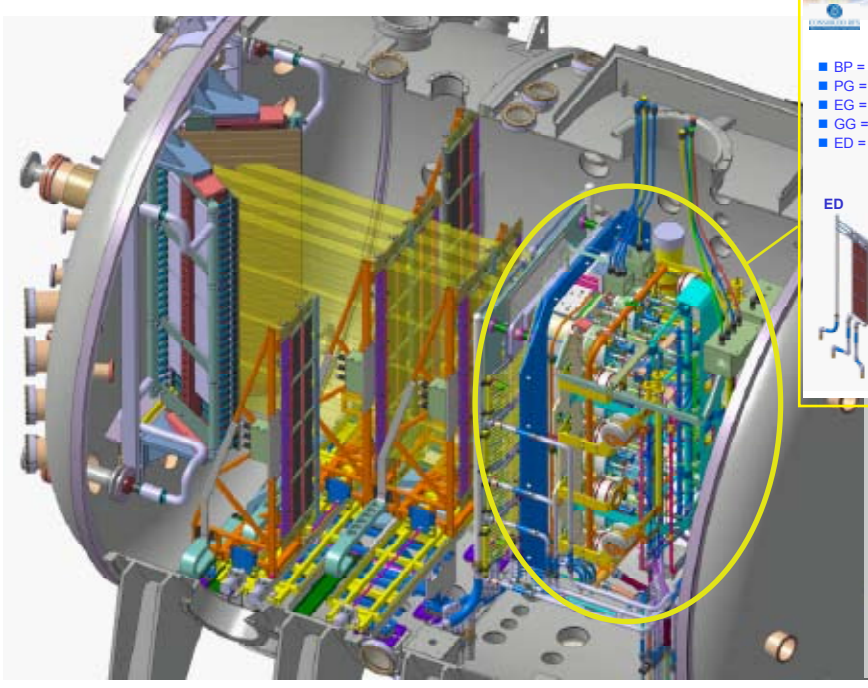
All the components made by Europe were contracted and the first installations are already underway.

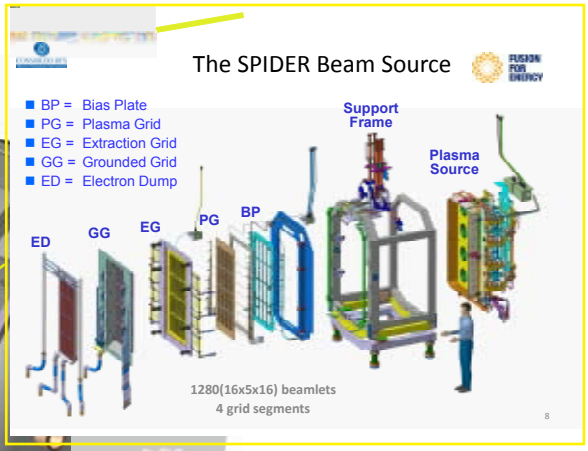
The Installation takes place in the experimental rooms made by Consorzio RFX.

Some components supplied by India have been already delivered in Padua.



SPIDER





On the left the cross-section of the vacuum chamber of SPIDER. On the right, the ion source, in the center, in yellow, the ion beam hitting the calorimeter, the function of which is to absorb the energy of the beam and to monitor the proper functioning of the source by means of systems of temperature measurement ... the figure above shows in detail the components of the source.

The first components of SPIDER are coming

In the top right: view of the vacuum chamber of SPIDER during the acceptance tests carried out in the factory at the Company Zanon sited in Schio (VI).

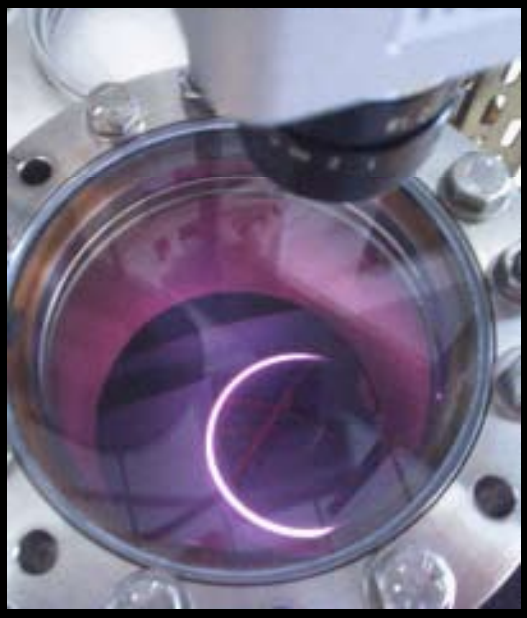
The vacuum chamber of cylindrical shape has a diameter of about 4 m and a length of 6m. The site installation is expected in February 2015.

In the bottom right: calorimeter, provided by INDIA, during acceptance testing at the PVA (D). The calorimeter was delivered to Consorzio RFX on 22 December 2014 and will be installed in the vacuum chamber in the middle of 2015.

Building 1
The main door of the shielding of SPIDER is raised to be placed in its final location. Given the exceptional weight of 120 tons, its handling required to use, in parallel, two cranes and skilled staff able to move the door to the millimeter. The concrete structure that will house SPIDER will serve to shield neutrons and radiation produced during the experimentation and will allow the access, in complete safety, to the main building during the research.

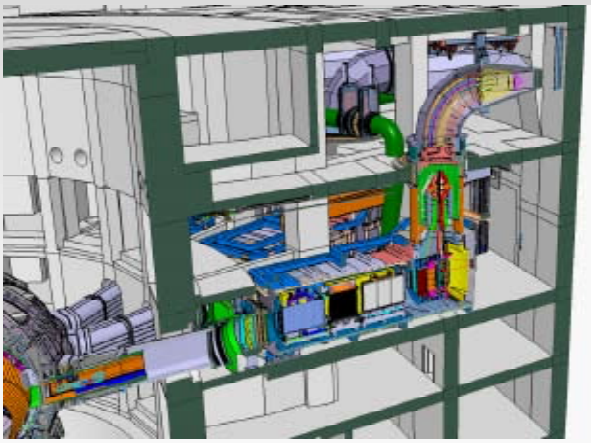
Details of the cabin shielded and isolated from ground for 100kV, which will host the electric systems of source power of SPIDER. The shielded cab is made of a metallic room completely closed of about 12x8 m2 mounted on insulating supports. The installation of HVD began on 26 January 2015.

Calibration phases of the radiation emitted by the tungsten windings electrically heated.



MITICA the injector

Position of MITICA in ITER



In ITER two systems made on the basis of the results of NBTF will be installed. In parallel to ITER, the experiments on MITICA and SPIDER will continue.

On the left: the injector MITICA connected to the power supply system through the transmission line of 1MV
In the center: the power supply system of the ion source.
On the right: the power supply system of the accelerator.

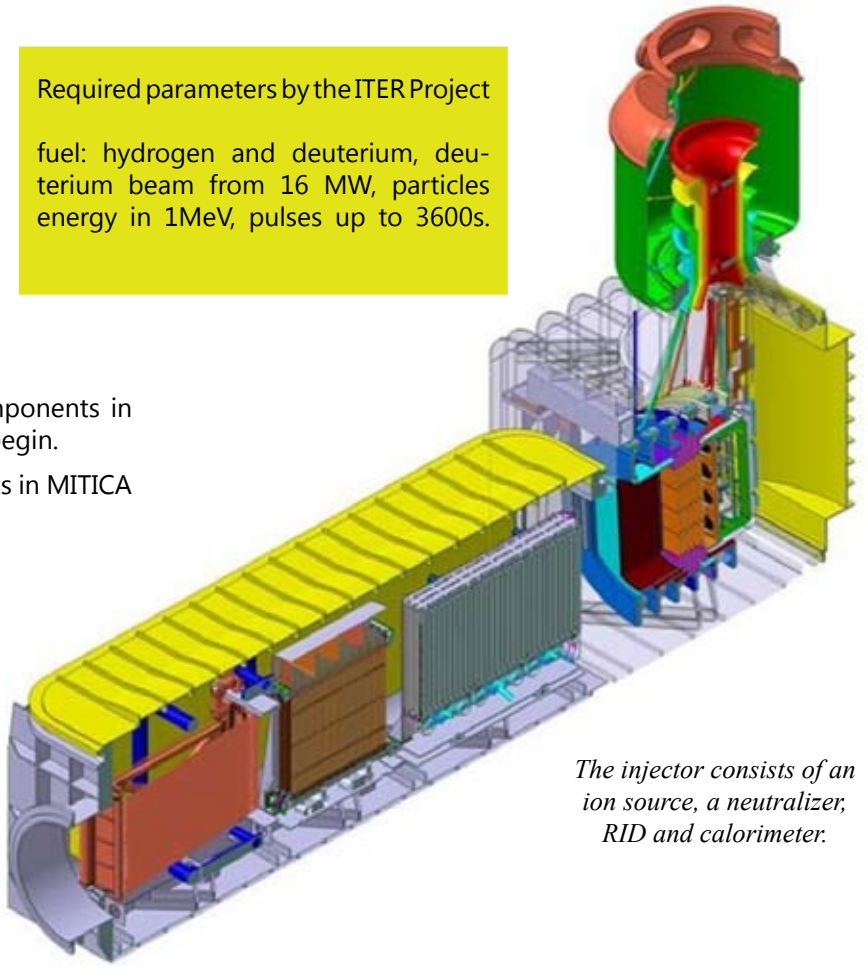
The injector scale prototype complete with all the auxiliary facilities where the R&D activities will be made for the development of ITER injectors.
The design of MITICA components is completed and the achievements undertaken.
Japan, in addition to Europe, significantly contributes to the manufacture and deliver of MITICA plants.

Required parameters by the ITER Project

fuel: hydrogen and deuterium, deuterium beam from 16 MW, particles energy in 1MeV, pulses up to 3600s.

At the end of 2015 the installation of components in high voltage (1MV) supplied by Japan will begin.

The expectation is to initiate the experiments in MITICA during 2018.



The injector consists of an ion source, a neutralizer, RID and calorimeter.

The manufacturing operations of MITICA include great works of containment of the experiment, entrusted to Consorzio RFX. It is a total of 10,000 tons of concrete distributed to a height of 19 meters, 15 wide and 30 long.

The equipments entrusted to Europe have been designed by Consorzio RFX. The preparation of the specifications for tenders has been completed and are ongoing proceedings for the award of contracts by Fusion for Energy.

The plant is completed with the high-voltage (1MV) power supply system supplied by Japan.

3D Model of the vacuum system of SPIDER e MITICA

Fornitura	Agenzia	Lancio gara
Vessel	F4E (Europa)	Già assegnata
Sorgente	F4E (Europa)	Q4 2014
‘‘Beam Line Components’’	F4E (Europa)	Q1 2015
Pompe criogeniche	F4E (Europa)	Q2 2015
Linea di trasmissione	JADA (Giappone)	Già assegnata (Hitachi)
HVD1 & Passante aria/gas	F4E (Europa)	In aggiudicazione
Passante vuoto/gas (HV Bushing)	JADA (Giappone)	Già assegnata (Hitachi Haramachi, Kyocera)
Alimentatori sorgente	F4E (Europa)	OCEM 2° lotto
Trasformatore isolamento a 1MV	JADA (Giappone)	Già assegnata (Hitachi)
Alimentatore acceleratore (AGPS-DCG)	JADA (Giappone)	Già assegnata (Hitachi)
Alimentatore acceleratore (AGPS-CS)	F4E (Europa)	Q3 2014
Impianto criogenico	F4E (Europa)	Q2 2014
Impianto gas SF6 isolamento	F4E (Europa)	Q3 2015

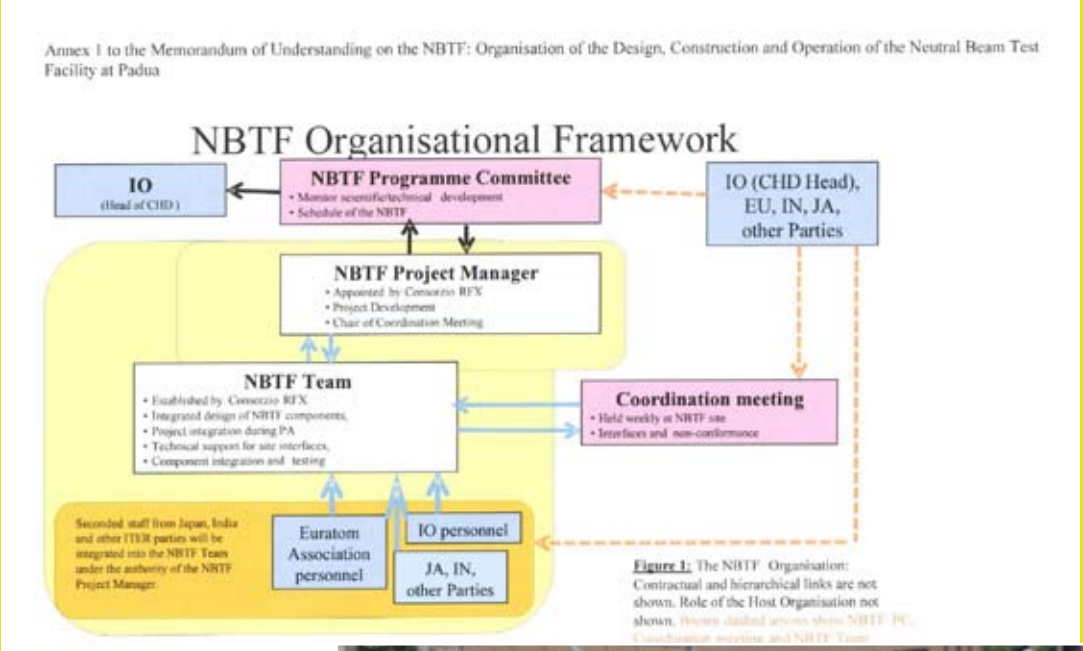
To achieve

Systems linking the existing high voltage sub-station in 400 kV and already used to power the RFX experiment and the experimental facilities MITICA & SPIDER.
It is cable connections in medium voltage with relative distribution panels.
Mobile shielding of MITICA, removable as it will be necessary to access to the injector for maintenance.
External fire protection systems designed to protect transformers in very high voltage provided by the Japanese Domestic Agency.
The installation can be initiated only following the completion of the Japanese supply.

Un' impresa internazionale cui partecipano Europa, Giappone e India con la realizzazione dei componenti scientifici e impianti di ricerca.

L'Italia è impegnata nella realizzazione degli edifici, infrastrutture e nella progettazione dì tutte le apparecchiature realizzate dagli altri partner.

Enti italiani coinvolti: CNR e INFN che hanno affidato al Consorzio RFX lo sviluppo delle attività a Padova, presso l'Area della Ricerca del CNR.



La complessa struttura organizzativa per le fasi di progettazione, costruzione e operazione dell'impianto è stata definita negli accordi internazionali.

L'ing. Vanni Toigo (sulla destra), Project Manager del Progetto PRIMA illustra a un giornalista (sulla sinistra) i componenti dell'impianto. Al centro, l'ing. Edoaro Ocello, Direttore dei Lavori

Sviluppo delle attività

Novembre 2006	Firma dell'ITER Agreement che stabilisce la realizzazione di NBTF
Dicembre 2011	Firma degli accordi internazionali per la realizzazione NBTF a Padova
Settembre 2012	Avvio della costruzione edifici
Giugno 2013	Inizio montaggi prefabbricati
Novembre 2014	Consegna dei primi edifici
Dicembre 2014	Avvio delle installazioni
Aprile 2015	Completamento degli edifici
Inizio 2016	Avvio sperimentazione di SPIDER
2018	Avvio sperimentazione di MITICA