



NATIONAL RESEARCH CENTRE
«KURCHATOV INSTITUTE»

RECENT RUSSIAN CONTRIBUTION TO THE DEVELOPMENT OF THE IGNITOR PROJECT

M.L. Subbotin
NRC «Kurchatov Institute»

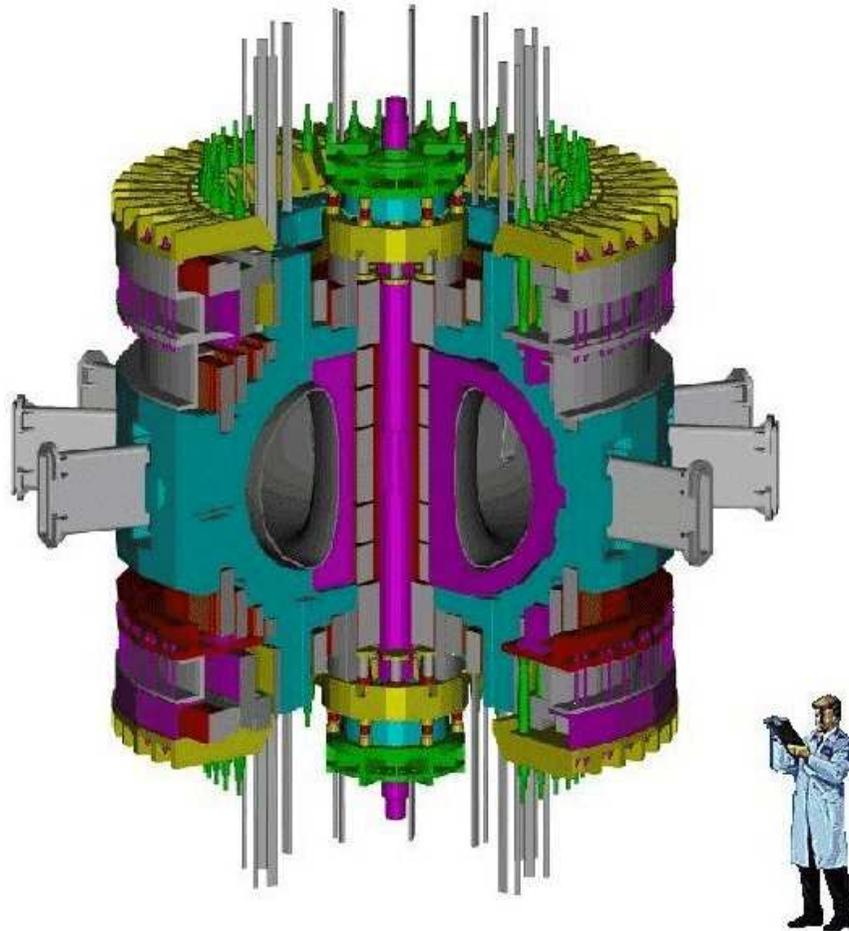
CREMLIN Workshop “The Russian-Italian IGNITOR Tokamak Project:
Design, status of implementation and international colaboration”

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RUSSIAN-ITALIAN PROJECT IGNITOR

IGNITOR MACHINE



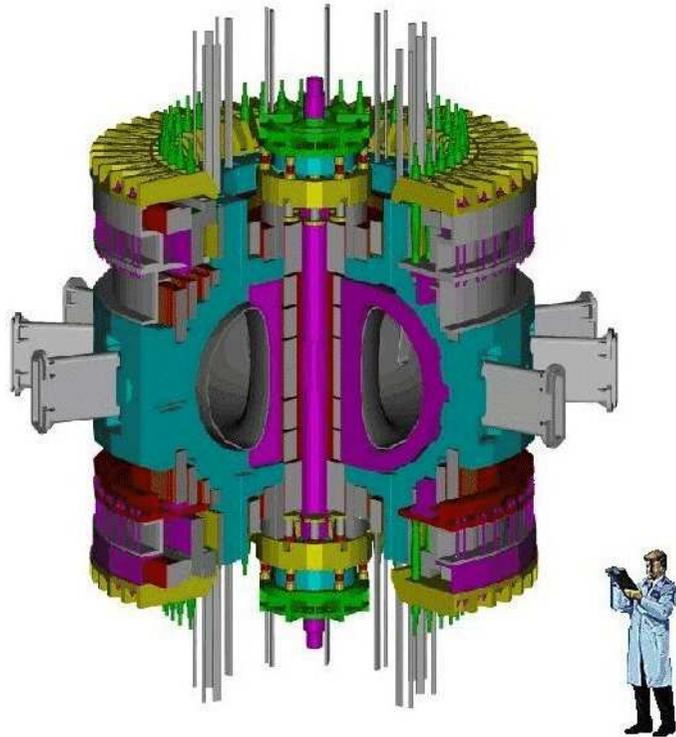
The purpose of the Russian-Italian «Ignitor» project is the creation of tokamak with a quasi stationary super strong magnetic field in which very strong current will heat up dense deuterium-tritium plasma up to 100–120 million degrees – necessary for ignition of thermonuclear fusion reactions.



RUSSIAN-ITALIAN PROJECT IGNITOR

BRIEF HISTORY (1)

IGNITOR MACHINE

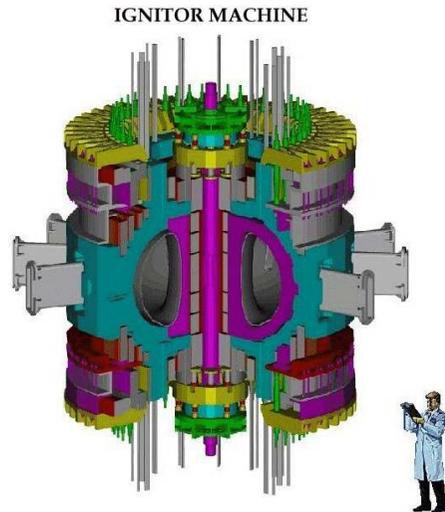


The project of a tokamak of IGNITOR was initially conceived as astrophysical experiment aimed on experimental confirmation of the theoretical models of ignition conditions of thermonuclear reactions on stars and was interested, first of all, for researchers in field of astrophysics.



RUSSIAN-ITALIAN PROJECT IGNITOR

BRIEF HISTORY (2)



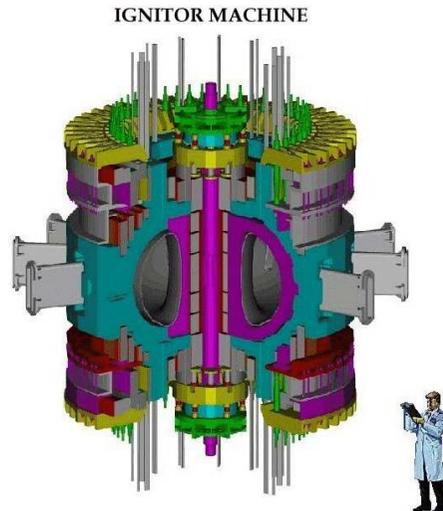
Since 1977 during many years Professor Bruno Coppi with his team worked under theoretical and physical basis of the "IGNITOR" project. As a result of their activity about 100 scientific papers described of various aspects of the IGNITOR project were published.

At the beginning of the 2000th years the project was prepared and presented to the Italian Government for acceptance and beginning of the construction. The location of tokamak "Ignitor" was planned at the Caorso site, district Piacenza in Northern Italy. Unfortunately for developers of the project, in this time the Italian Government adopted a number of the laws and rules which strongly limited nuclear activity on the territory of country, as a result of these events the Ignitor project was frozen.



RUSSIAN-ITALIAN PROJECT IGNITOR

BRIEF HISTORY (3)



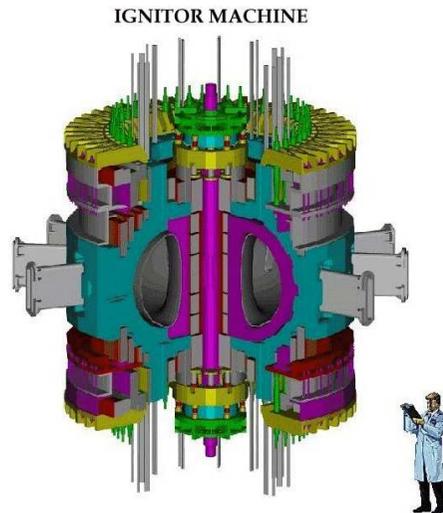
In 2006 during of the meeting between Acad. E. Velikhov and Prof. B. Coppi there was the discussion about "Ignitor" project, on the result of this discussion Acad.E.P. Velikhov suggested to realize the Ignitor project on the Russian territory, Prof. B. Coppi accepted this suggestion. The initiative was supported by the Leaders of the Russian Federation and Italian Republic.

In 2009 during of high level summit in Italy was signed the Memorandum of Understanding between Russian Federation and Italian Republic on cooperation in field of nuclear science, including Ignitor Project. In 2010 the first joint Russian-Italian meeting on the project of a tokamak "Ignitor" was held.



RUSSIAN-ITALIAN PROJECT IGNITOR

BRIEF HISTORY (4)



2010 - Memorandum of Understanding between the Ministry of Education and Science of the Russian Federation and the Ministry of Education, Universities and Research of the Italian Republic was signed on cooperation in the field of the tokamak «IGNITOR».

2013 - Decision to elaborate the Conceptual Design Report of the tokamak IGNITOR was taken during the Meeting between the NRC «Kurchatov Institute» Director Professor M.V. Kovalchuk and the INFN President Professor F. Ferroni.

2013 - Joint Russian-Italian Working Group was formed for the Elaboration of the CDR of the tokamak IGNITOR.

2014 - Elaboration of the CDR of the tokamak IGNITOR by the joint Russian-Italian Working Group.



Conceptual Design-Report (CDR) of the Russian-Italian tokamak IGNITOR



May, 2015 - Russian-Italian joint Working Group* completed CDR of tokamak IGNITOR.

2016 – 2017 - The Russian-Italian Intergovernmental Agreement on realization of the tokamak IGNITOR project is under preparation.

*** Working Group consists of NRC «Kurchatov Institute», TRINITI/Rosatom, INFN members**



THE MAIN GOAL AND MISSION OF THE IGNITOR PROJECT

The principle goal of the IGNITOR Project

To achieve the ignition conditions in dense plasma by ohmic heating only due to powerful toroidal current in super strong magnetic fields.

The mission of the IGNITOR Project

- 1. The confinement of the high current plasma in a super strong magnetic field;*
- 2. Testing high-temperature superconductors for EMC designed to create the magnetic fields up to 13-15 T;*
- 3. The development of the new diagnostic systems for control dense fusion plasma processes;*
- 4. The receiving a new experimental dates on high flux plasma-wall interactions, influence of fusion neutrons flux on construction materials and so on.*



PARTICIPANTS OF THE IGNITOR PROJECT

From the Russian side organizations responsible for the implementation of the project are:

NRC «Kurchatov Institute» (scientific coordinator),

SC «Roastom» (infrastructure).

From the Italian side responsible organization is:

Istituto Nazionale di Fisica Nucleare (INFN) (tokamak load assembly).



ZONES OF THE RESPONSIBILITY BETWEEN PARTICIPANTS OF THE IGNITOR PROJECT

The responsibilities of the Russia in the IGNITOR Project will be are:

- *TSF complex TRINITI including experimental and assembling halls;*
- *Power and Engineering infrastructures;*
- *Tritium plant;*
- *Cryogenic plant.*

The responsibilities of the Italy in the IGNITOR Project will be are:

- *manufacturing and delivery tokamak IGNITOR to the Russian site;*
- *IGNITOR tokamak load assembly;*
- *additional equipment for installation of tokamak IGNITOR to the Russian site.*

The common Russia and Italy responsibilities will be are:

- *Fuel injection system;*
- *Physical and technological diagnostics;*
- *The control, data acquisition and remote access systems*



PERSPECTIVES IN THE IGNITOR PROJECT DEVELOPMENT

If the Russian-Italian negotiations will successfully finalized and Inter-Government Agreement on the IGNITOR project realization will signed the implementation of the preliminary schedule may be next:

- 1. **First stage** - during 3-4 years to develop and accept by Russian Government Regulatory Body (Russian State Expertize) the Technical Design Project;*
- 2. **Second stage** - during next 3-4 years Italian Party manufactures of the tokamak IGNITOR and deliveries it to the TRINITI site. Russian Party manufactures necessary equipment for modernization of power and engineering infrastructure and provides the modernization of infrastructure TRINITI site under requirements of the IGNITOR project;*
- 3. **Third stage** – during 1-2 years Russian and Italian Parties jointly provides the assembling of IGNITOR tokamak and installation works of all infrastructures and achieving of the first plasma.*



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

The first russian work on the Ignitor project was carried out in 2014 and it was connected with the determination of technical requirements of the Ignitor Project to Power and Engineering Infrastructure of the TRINITI site (Moscow Region, Russia) as place of location tokamak Ignitor. During of this work was provided analysis of more than 40 papers and presentations executed by our Italian colleagues and described different engineering systems which should provide the operating of tokamak.

As a result were determined 17 crucial systems necessities for tokamak operating and described of it's parameters.

Further it was provided the comparison of these parameters with possibilities of the Power and Engineering Infrastructure of TRINITI site.



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

TECHNICAL REQUIREMENTS OF THE IGNITOR PROJECT

REQUIRED TRITIUM CHARGE PER EXPERIMENTAL DAY - 3G/DAY

❖ *WATER COOLING SYSTEM (COOL-DOWN& RE-COOLING)*

*STEADY-STATE REGIME: 200 m³/hour,
IN PEAK-LOADING REGIME: 730 m³/hour*

❖ *VACUUM SYSTEM*

Primary Vacuum (Plasma Chamber)		
Total Volume	V_{PC}	15 m ³
Operating Pressure	P_u	2.5×10^{-9} mbar
Pumping Speed	Q_D	8000 l/s
Secondary Vacuum (Interspace Cryostat-Machine)		
Total Volume	V_{Cry}	~200 m ³
Operating Pressure	P_u	1×10^{-4} mbar
Pumping Speed	Q_D	420 l/s



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

No	System	IGNITOR Project	TRINITI Site	Notes
1	Tokamak IGNITOR	Main parameters (in assembling): Height– 10 m; Diameter – 8 m; Weight – 776 ton; Load on one support – 194 ton;	Main parameters of experimental hall: Geometrical parameters 40x40x40 m; Safe load on the basis ≥ 1000 ton	Acceptable
2	Pulsed power supply system	1 GW during 10 sec	1 GW from the GRID during up to 100 sec; 1 GW from four shock turbo- generators for short time (≤ 10 sec)	1 generators to be modernized
3	Steady-state power supply system	380 MW	330 MW from the supply line; 80 MW at the electric substation “Lesnaya” as additional	to be modernized
4	Primary Vacuum (Plasma Chamber)	Total Volume: 15 m ³ Operating Pressure: 2.5×10^{-9} mbar Pumping Speed: 8000 l/s	Vacuum System is working	to be modernized
5	Secondary Vacuum (Interspace Cryostat-Machine)	Total Volume: ~200 m ³ Operating Pressure: 1×10^{-4} mbar Pumping Speed: 420 l/s	Vacuum System is working	to be modernized



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

No	System	IGNITOR Project	TRINITI Site	Notes
6	Cryogenic system (Cool-down & Re-cooling)	Mass-flow: 1940 g/s Expected power input: 4700 kW	Cryogenic System is working	to be modernized
7	Cryogenic system (Steady-state)	Mass-flow: 1850 g/s Expected power input: 3200 kW	Cryogenic System is working	to be modernized
8	Nitrogen system (Cool-down & Re-cooling)	Mass-flow: 1700 g/s Expected power input: 700 kW	Vacuum System is working	to be modernized
9	Water cooling system (Cool-down & Re-cooling)	Mass-flow: 460 m ³ /h	Vacuum System is working	to be modernized
10	Additional heating system	System is described	Required adoption to the site	TBD
11	Working gaseous system	No dates	TBD	TBD
12	Tritium system	Required Tritium charge per experimental day - 3g/day	Tritium system is available up to 10 g/day	Approval is required



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

No	System	IGNITOR Project	TRINITY Site	Notes
13	Remote handling system	System is described	Required adoption to the site	TBD
14	Pellet-injection system	System is described	Required adoption to the site	TBD
15	HVAC System	No dates	TBD	TBD
16	Radiological and environmental monitoring system	System is described	Should be investigated under domestic Laws and Rules	TBD
17	Central control, data acquisition, interlock and alarm systems	No dates	TBD	TBD



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

Preliminary risks analysis of the IGNITOR Project on realization phase

In 2016 jointly with our Italian colleagues was carried out the work on the preliminary risks analysis of the IGNITOR Project realization phase. During the pre-processing of the available data on the IGNITOR project, the following categories of risks that may occur during the project realization phase were identified:

- ***political;***
- ***economical;***
- ***achievement of the main goal of the project;***
- ***technical and technological risks;***
- ***risks of implementation of the scientific research program;***
- ***environmental, safety and socio-economical risks.***



RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

Ignitor siting at the TRINITI site in Russian Federation

In 2016 jointly with our Italian colleagues the deterministic evaluations (radioactive inventory and dose population codes) have been performed. The preliminary radiological impact analysis for the normal operation and the main accidental sequences of Ignitor, in case of its localization in the TRINITI site in Russia, was made.

The main results shown that the IGNITOR machine, both during routine operation and accidental sequences, presents a negligible radiological impact:

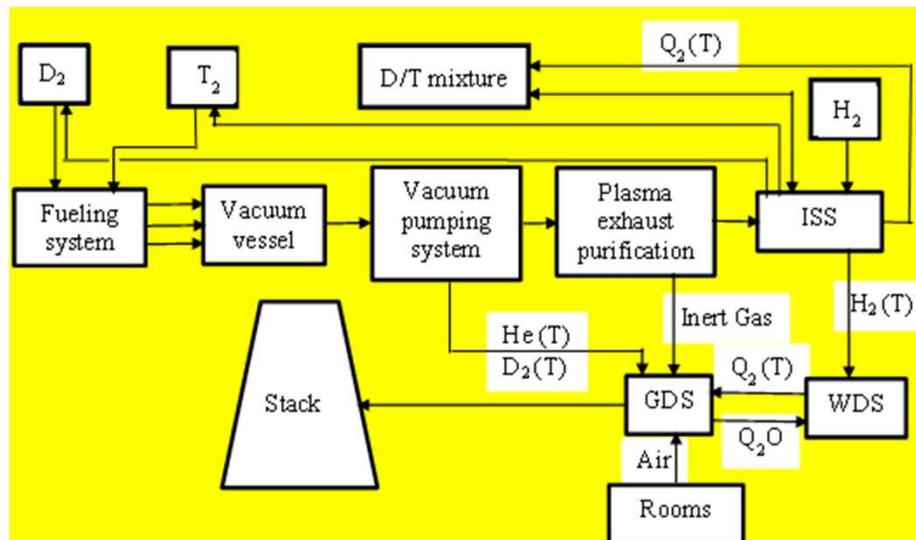
- ❖ *The routine doses to the critical group are, as a maximum value, $3.29E-6$ $\mu\text{Sv}/\text{y}$ (with the stack), and $3.92E-6$ $\mu\text{Sv}/\text{y}$ (without it).*
- ❖ *The maximum dose to the critical group, in case of the worst accidental sequence (failure of GIS pipe in bunker), is less than 0.11 mSv, below any relevant limit for any emergency countermeasure.*

RUSSIAN CONTRIBUTION IN THE DEVELOPMENT OF THE IGNITOR PROJECT

Concept of Tritium Processing and Confinement in Fuel Cycle of Ignitor

In 2016 by the Russian specialists was developed Concept of Tritium Processing and Confinement in Fuel Cycle of Ignitor. During this work was

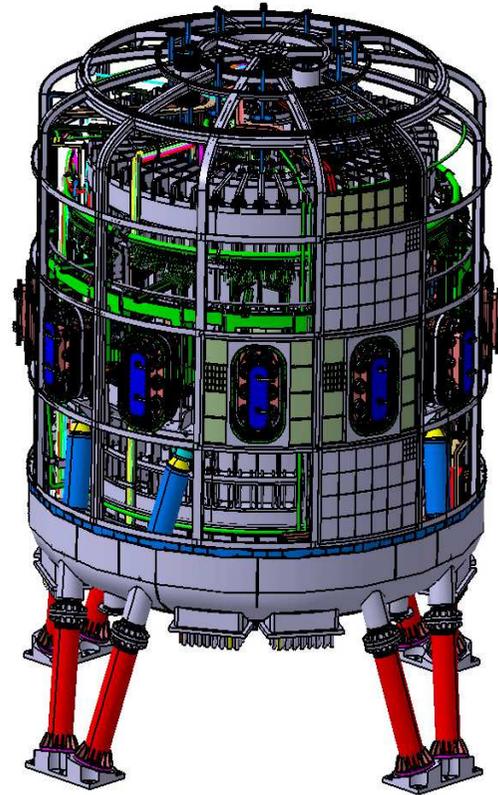
update the concept of the tritium Processing and Confinement in Fuel Cycle of Ignitor developed in early 2000th by Italian specialists. The achieved results shown more effectiveness and less expensive solutions in comparison with early developed and may be best basis for further development of Ignitor Fuel Cycle concept.





CONCLUSION

1. At present the Ignitor Project didn't lose the importance for world fusion researches and Russian scientists in cooperation with Italian colleagues tries to accelerate Russian-Italian Inter-government Agreement on realization of the project by their one's own current scientific contributions.
2. Ignitor Project very strong differ by own physical nature from other fusion projects and this make his very interesting for careful researches.
3. The success of the Ignitor Project may open a new, may be greatly more easy, way to achieve the ignition of fusion reaction.
4. The Ignitor Project possesses the huge potential for innovation decisions and new technologies in different field of science and engineering.
5. The Ignitor project will require to create unique, on the wide basis, research staff of experimenters, theorists, analysts and engineers.



Thank you for your attention!