Safety during the Neutral Beam Test Facility starting operations

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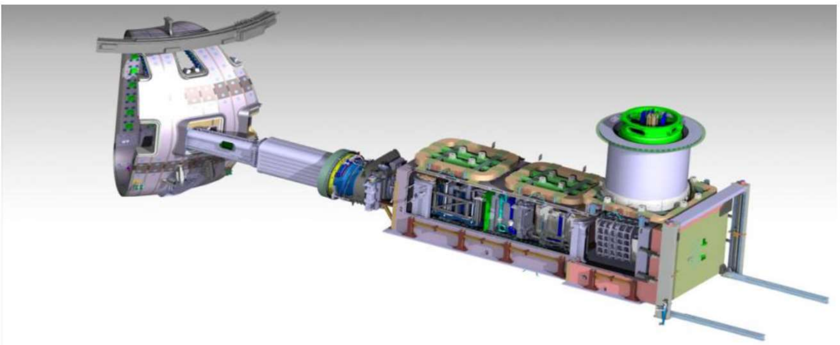
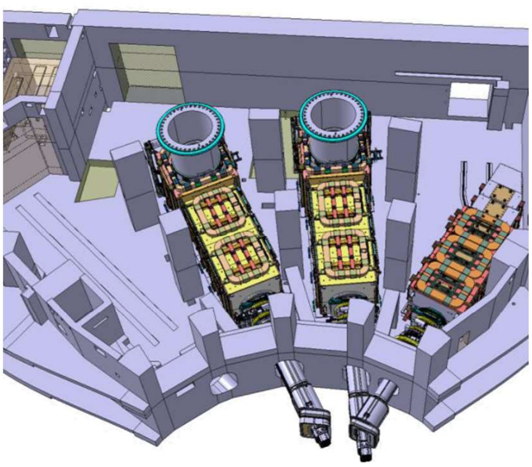
Negative ion beams in ITER



- 2 (+1) HNB: Heating Neutral Beam
- 1 DNB: Diagnostic Neutral Beam
- NBTF: Neutral Beam Test Facility



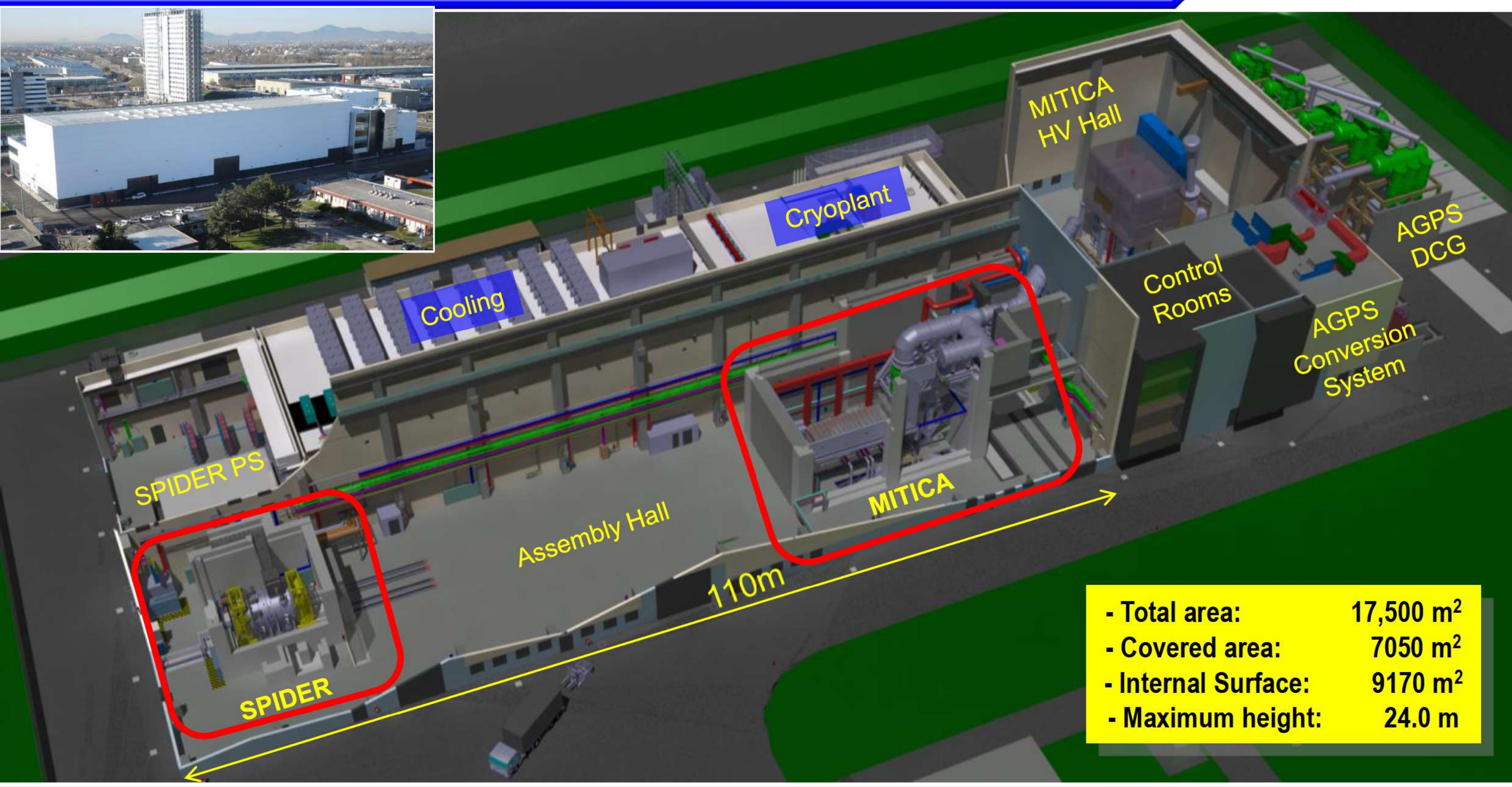
2 HNBs (+1): deuterium
- $I = 40$ A
- $V = 1$ MV
- $t_{pulse} = 3600$ s
- $P_{beam} = 16.5$ MW

EUDA & JADA procurement

1 DNB: hydrogen
- $I = 60$ A
- $V = 0.1$ MV
- t_{pulse} = 3s every 20s
- Modulation = 5Hz

INDA procurement

Progress in the ITER Neutral Beam Test Facility



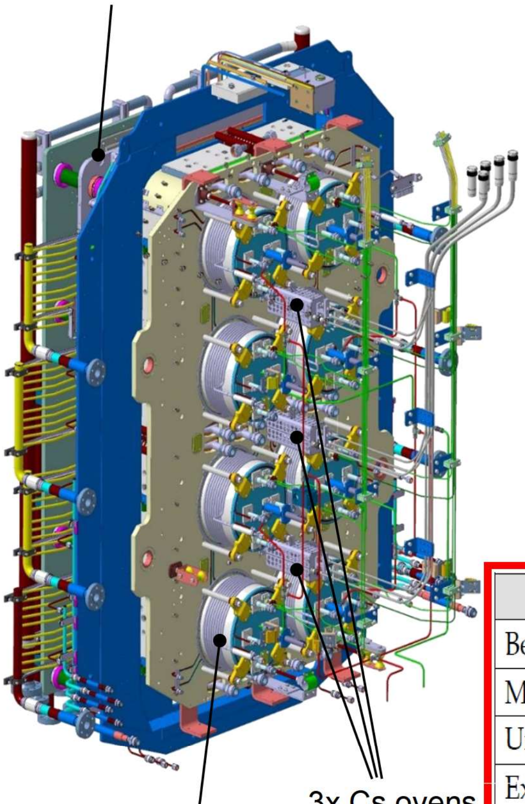
- Total area:	17,500 m^2
- Covered area:	7050 m^2
- Internal Surface:	9170 m^2
- Maximum height:	24.0 m

NBTF hosts two experiments: the negative ion source **SPIDER** and the 1:1 prototype of the ITER injector **MITICA**

Each experiment is inside a concrete biological shield against radiations and neutrons produced by the injectors

Thanks to these shieldings the assembly/maintenance area will be fully accessible also during experiments

SPIDER: full scale prototype of HNB/DNB ion source

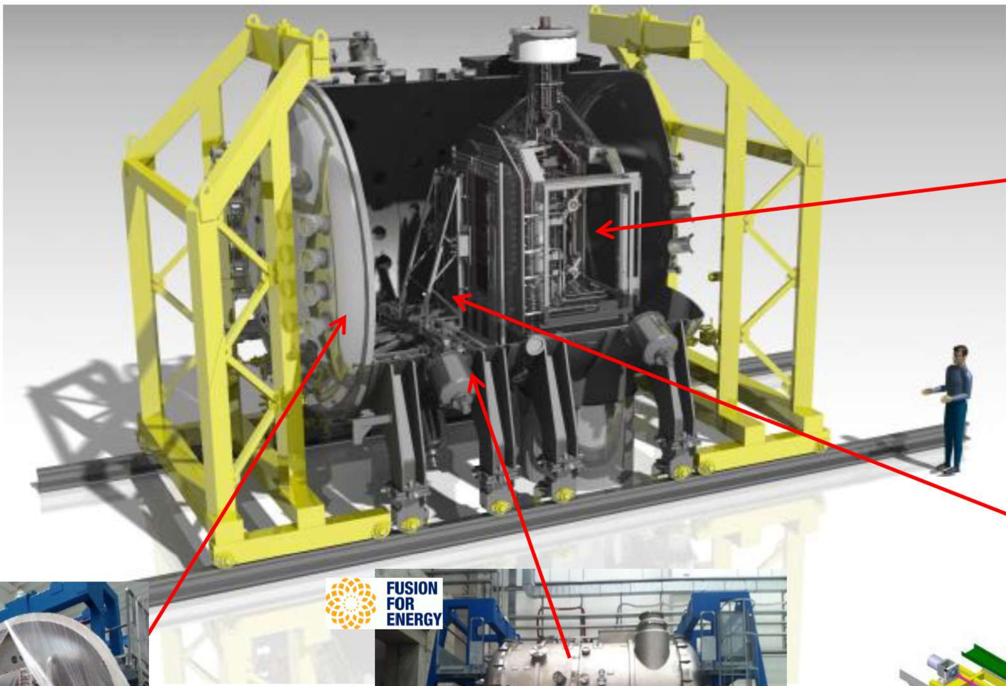


- Optimisation of production of negative ions (over an area of ~1.5m^2) in terms of:
  - Extracted current density
  - Uniformity
  - Stability
  - Co-extracted electron fraction

	Unit	H	D
Beam energy	keV	100	100
Maximum Beam Source pressure	Pa	<0.3	<0.3
Uniformity	%	±10	±10
Extracted current density	A/m^2	>355	>285
Beam on time	s	3600	3600
Co-extracted electron fraction (e^-/H^-) and (e^-/D^-)		<0.5	<1

SPIDER Components

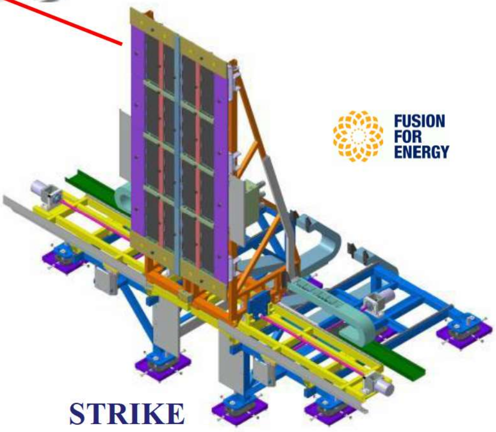
Vacuum-insulated beam source



Beam Source

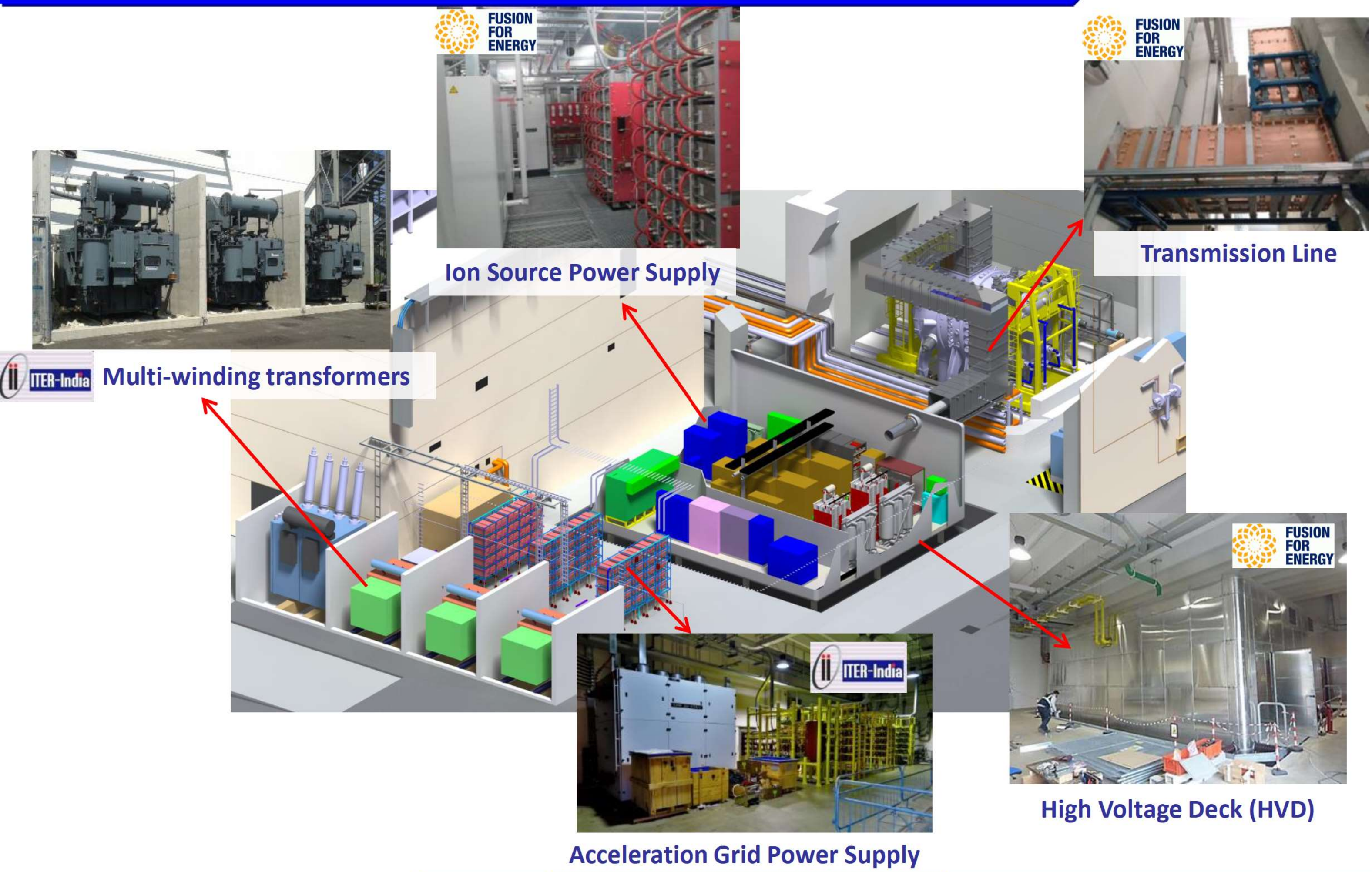
Beam Dump

Vacuum Vessel



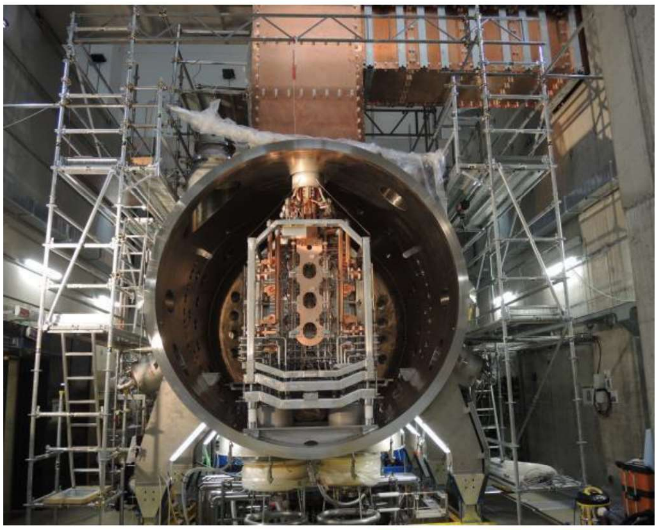
STRIKE
High resolution calorimeter

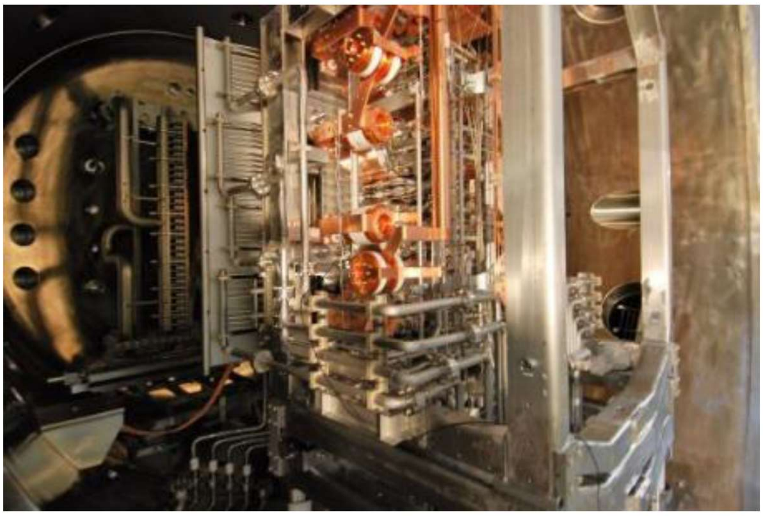
SPIDER power supplies

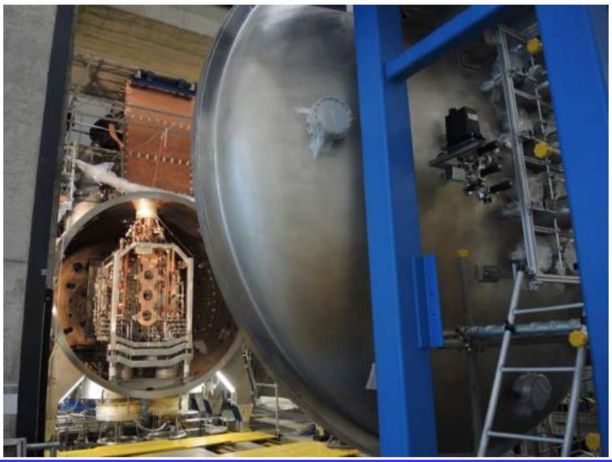


SPIDER beam source installation

- In March 2018
  - all electrical, hydraulics and diagnostic connections done, then vacuum vessel lid closed
  - leak test of hydraulic circuits from external flanges started

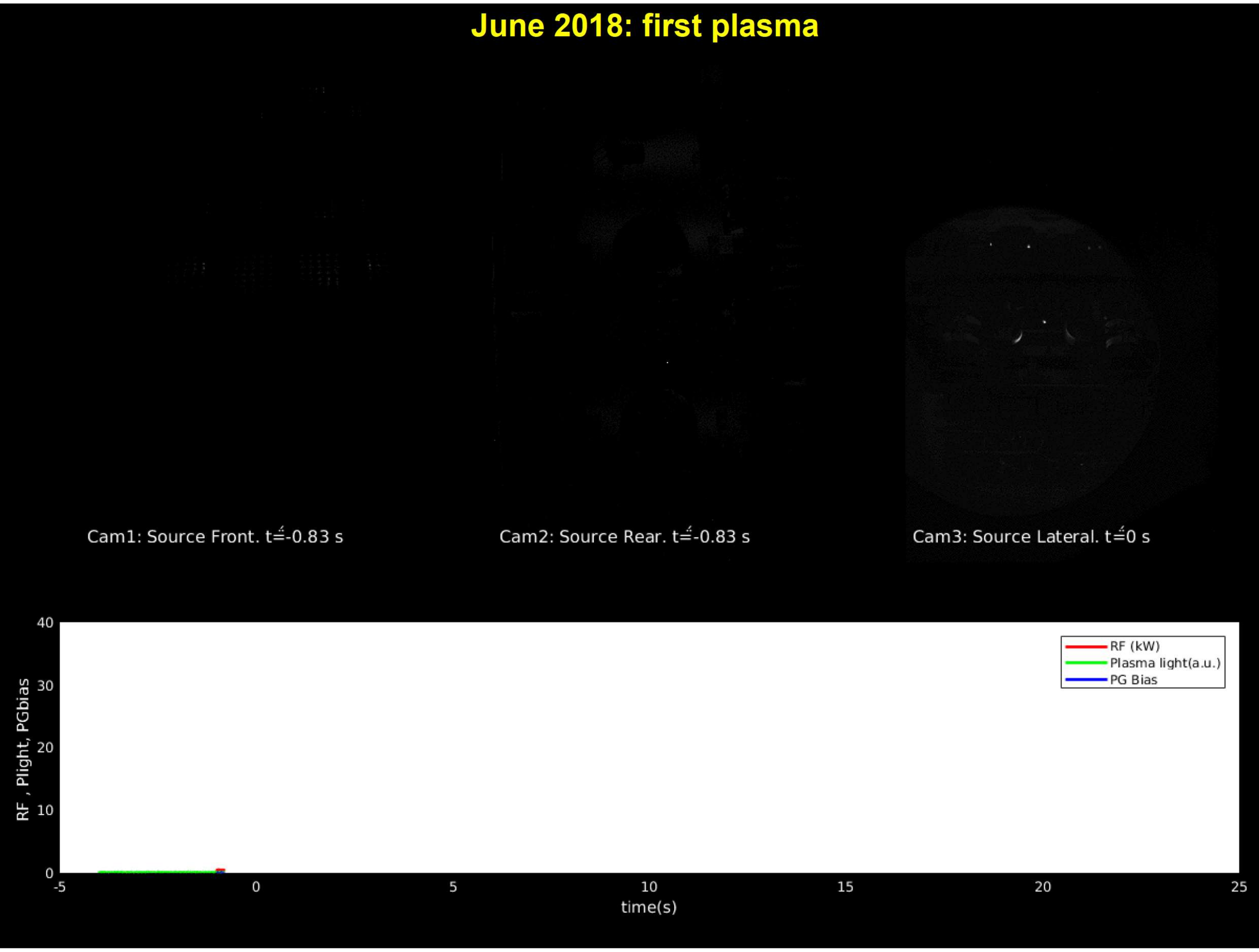






First SPIDER operations

- SPIDER operation started on 4 June 2018
- After some tuning, first plasma ignition on 6 June 2018 with 1/4 source
- Inauguration ceremony on 11th June 2018

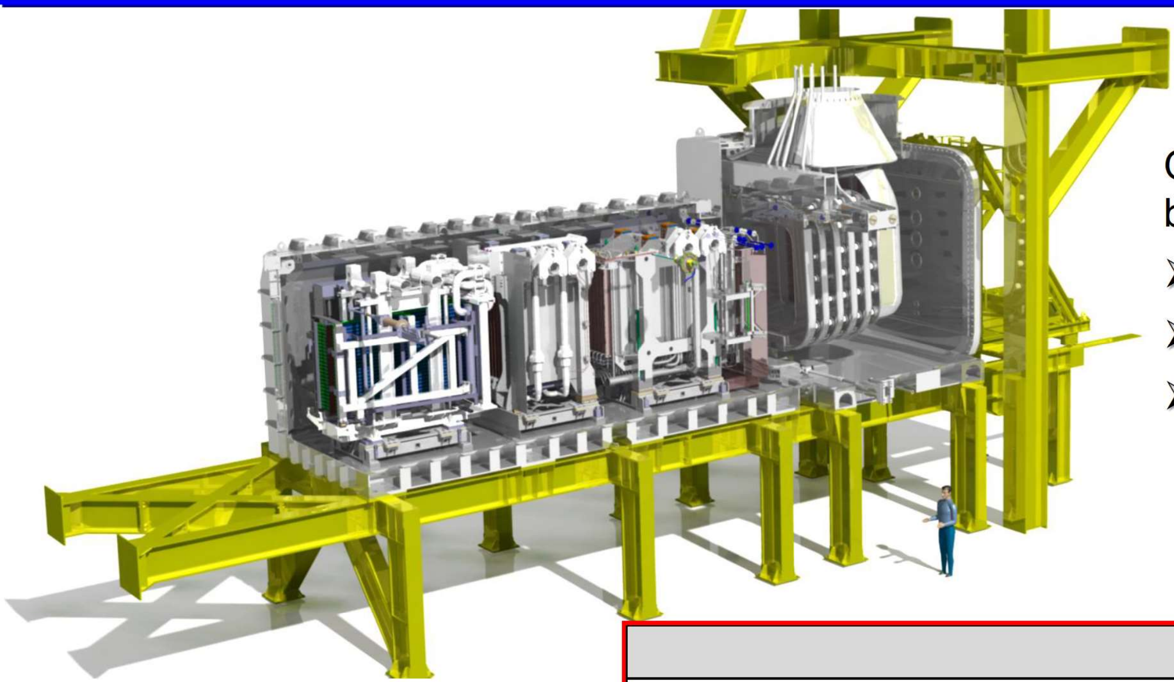


June 2018: first plasma
Cam1: Source Front. t=-0.83 s
Cam2: Source Rear. t=-0.83 s
Cam3: Source Lateral. t=0 s
RF , Plight, PGbias
time(s)
RF (kW)
Plasma light(a.u.)
PG Bias

SPIDER status

- Experimentation started in 2018
- Plants and diagnostics entering into operation one by one via dedicated commissioning campaigns
- Characterisation of source and beam in progress
- Increase of parameters in 2019

MITICA full scale prototype of ITER HNB

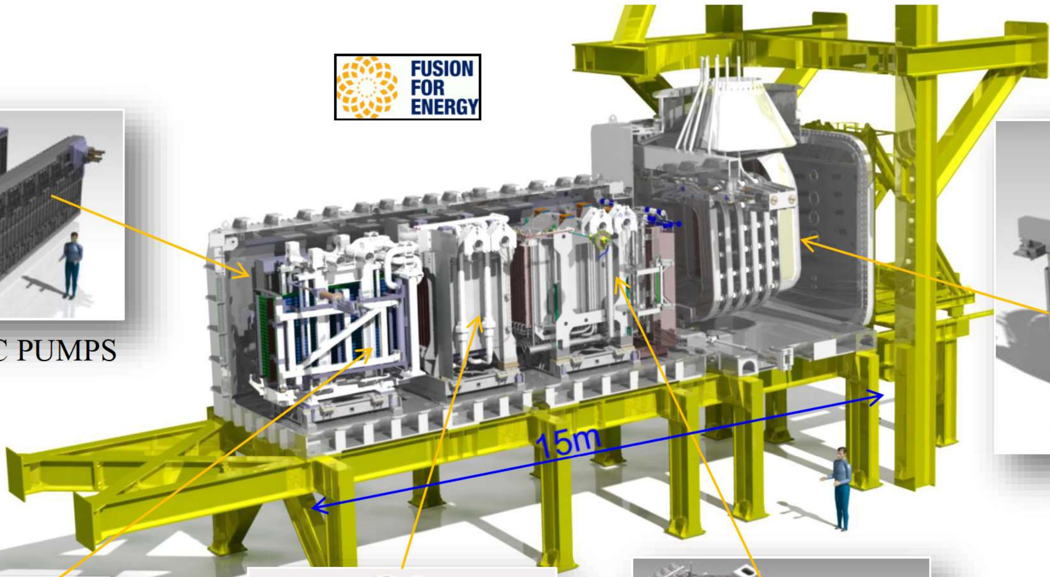


Optimisation of neutral beam in terms of:

- Performances
- Reliability
- Availability

	Unit	H	D
Beam energy	keV	870	1000
Acceleration current	A	46	40
Max Beam Source pressure	Pa	0.3	0.3
Beamlet divergence	mrad	≤7	≤7
Beam on time	s	3600	3600
Co-extracted electron fraction (e^-/H^-) and (e^-/D^-)		<0.5	<1

MITICA components

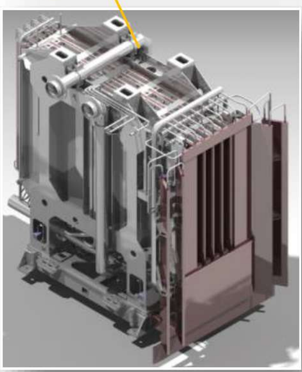


CRYOGENIC PUMPS

BEAM SOURCE

CALORIMETER

RESIDUAL ION DUMP



NEUTRALIZER

Procurement contracts of mechanical components are all in progress

Beam Source procurement is in the critical line. Procurement contract signed in 2018; delivery expected in 2022

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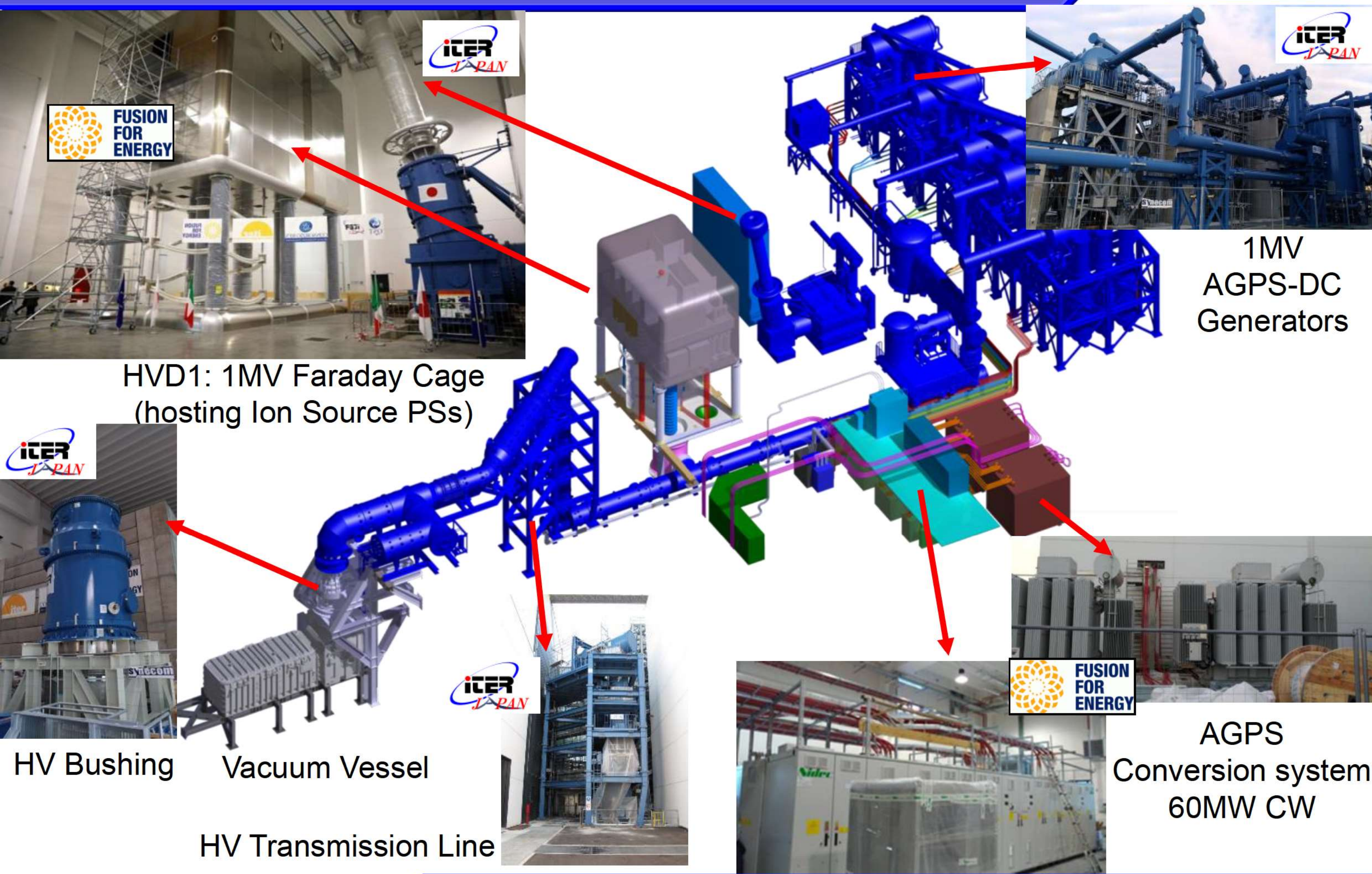
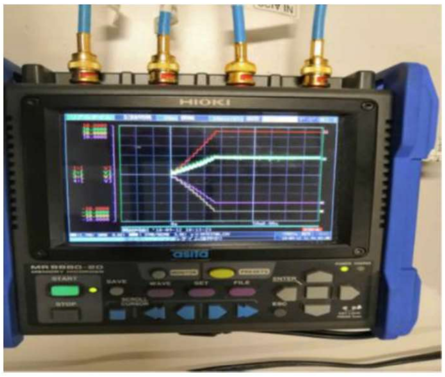
MITICA power supply system

CONSORZIO RFX *Ricerca Formazione Innovazione*



Insulating tests: 1.2MV (1h),1.06MV (5h)



1st STEP 1200kV-1 HOUR

2nd STEP 1060kV-5 HOURS

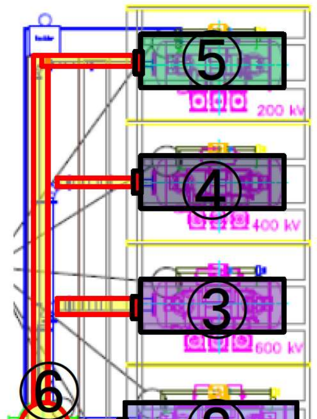
First HV insulating tests (on AGPS-DCGs and on TL) successfully passed

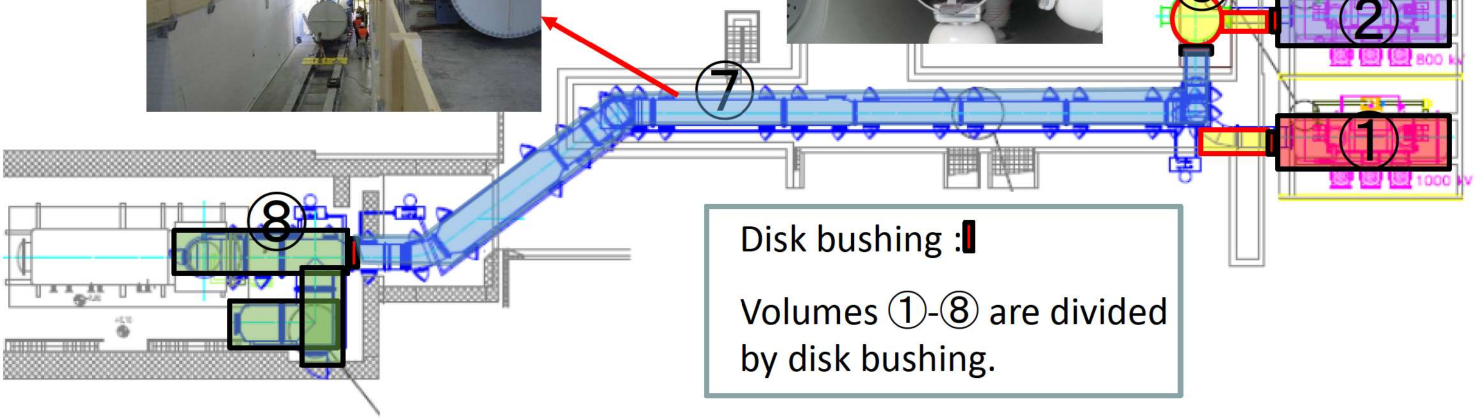
MITICA status

- High voltage power supplies almost completed and under test on-site
- Other auxiliary plant systems under installation and/or in commissioning phase
- All procurement contracts for mechanical components in progress
- Expected delivery on site of Beam Source in 2022

Safety: pressure vessel verification

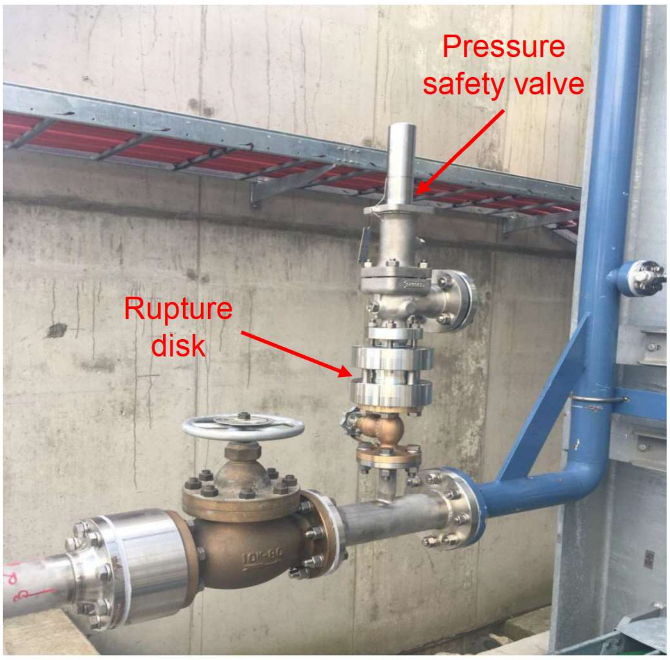
- 8 gas compartments (closed volumes) separated by insulating Disk Bushings;
- Filled with SF_6 at 6bar abs rated pressure, containing high-voltage electrical equipment
- No PED applicable ⇨ Verification carried out by INAIL according to VSR Standard - Italian Ministerial decree 1 December 1980 and subsequents
  [Disciplina dei contenitori a pressione di gas con membrature miste di materiale isolante e di materiale metallico, contenenti parti attive di apparecchiature elettriche (G.U. 11 febbraio 1981, n. 40)]





Safety: overpressure valve

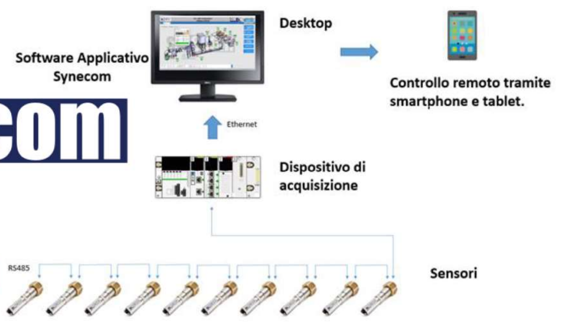
- To limit incidental overpressure, each compartment is provided with a safety relief valve (upstream rupture disk in series with a pressure safety valve)
- In case of overpressure inside a compartment, the disk breaks and the pressure safety valve lets reduce the overpressure, self reclosing when the pressure goes down at its normal value (this way avoiding to release in atmosphere all the gas contained in the compartment).
- The upstream rupture disk allows to avoid undue SF_6 release in case of small leakage of the overpressure valve.



Safety: SF_6 monitoring system

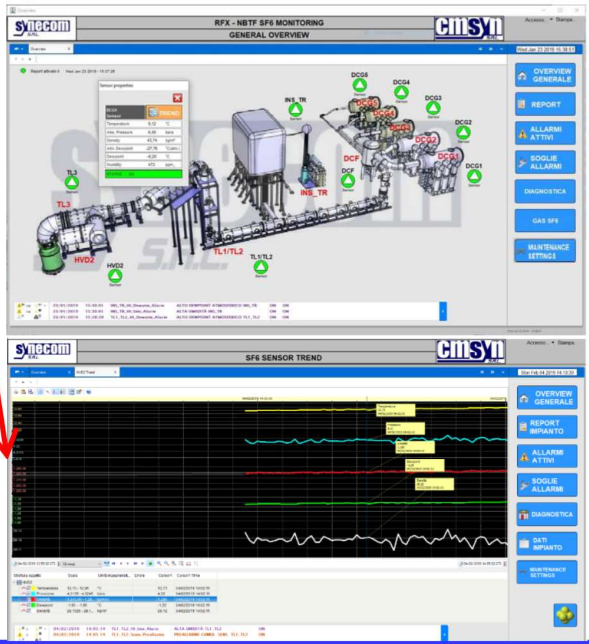
SF_6 is an excellent insulating gas, but because of its high global warming potential the responsible handling and strict leakage control is mandatory ⇨

synecom S.R.L.

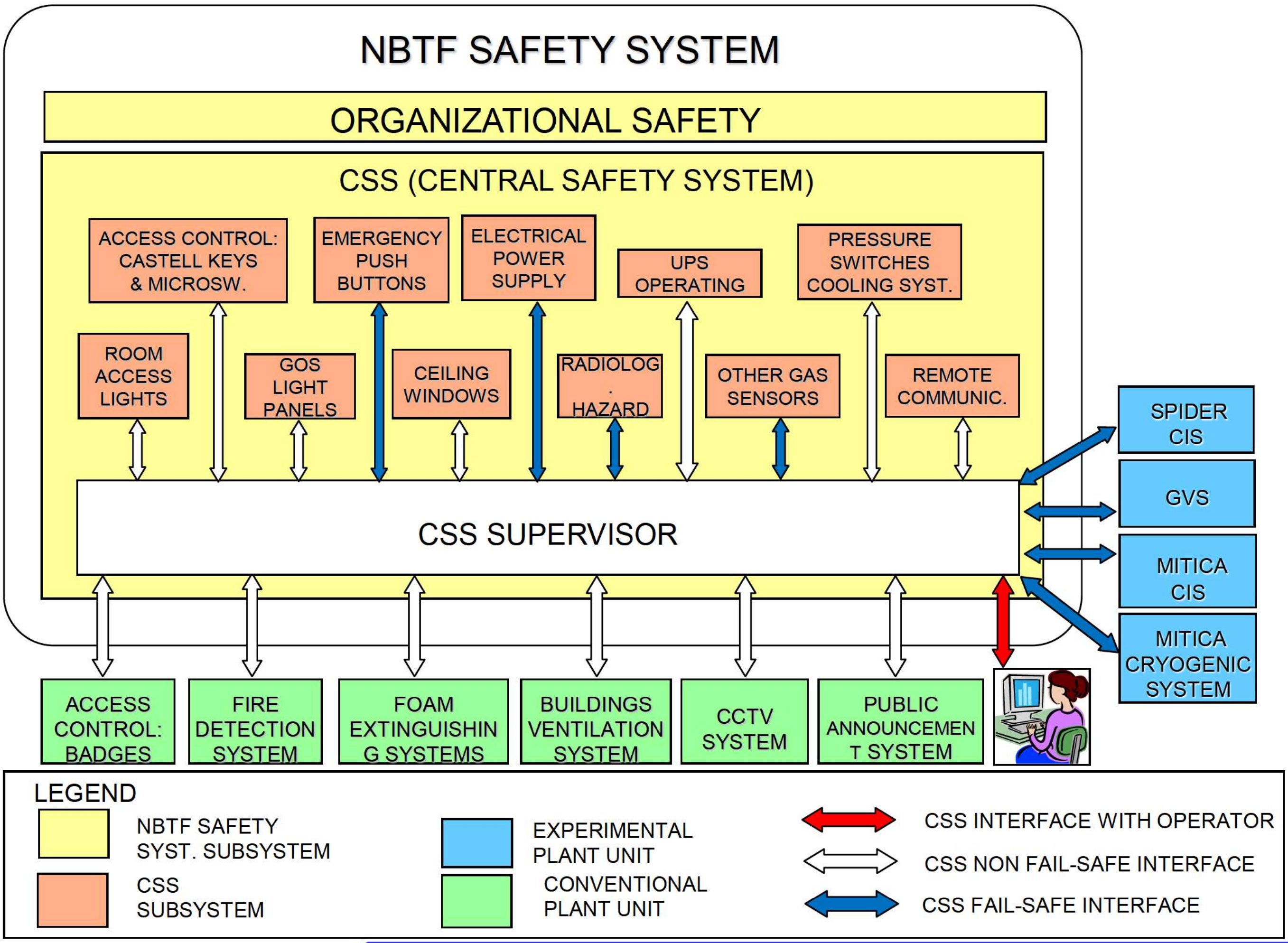


Online monitoring system

- *developed by a specialized Company, to be tested in NBTF, to control SF_6 gas status (density, temperature, pressure and humidity) to prevent any leakage to the environment*
- *One transducer per SF_6 compartment (gas density, temperature, pressure, humidity) ⇨ PLC and PC Desktop with dedicated software for*
  - *data visualization / trend of density, temperature, pressure and humidity*
  - *adjustable «low density» and «high moisture» alarm thresholds*
  - *gas leakage quantity evaluation*
  - *automatic drawing up of report (EU format like) for annual plant leakage declaration (according to EU517/2014, EU1191/2014, DPR 146/2018)*
  - *Possible connection from remote (via ModbusOver TCP/IP, IEC-60870-5-104).*
  - *Transducers provided with self diagnostic*



NBTF Safety System

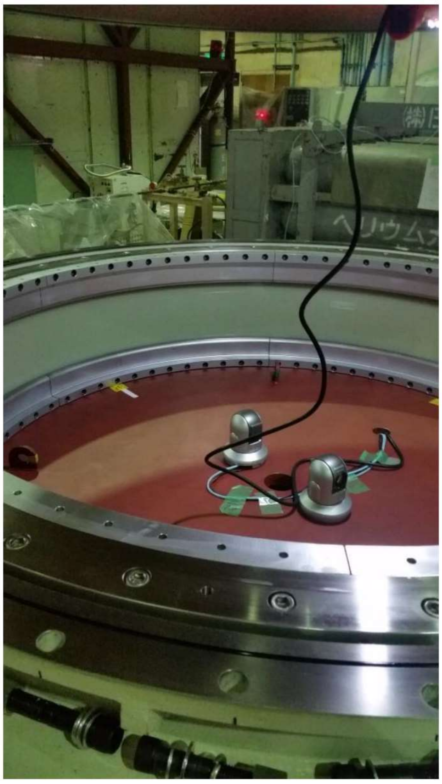


RFX – INAIL Cooperation Agreement

INAIL and the Consorzio RFX collaborate by developing research projects of common interest; training and training activities aimed at spreading knowledge among workers of the specific risks related to the operation of the machines that make up the plant in question and the methods of using them in safe conditions. ⇨

Operation purviews

- ❑ *Issues related to superheated water systems to dispose of the heat produced by the Neutral Beam, the discharges of the cooling water circuit, certification and commissioning of the storage facility for sulfur hexafluoride gas (SF_6).*
- ❑ *Installation of safety devices, such as valves and rupture disks, taking into account the danger to the environment of the SF_6 and Italian legal requirements.*
- ❑ *Operations:*
  - *seismic risk*
  - *non-pressurized parts, safety accessories, equipment not directly connected to the ultra-high voltage line, SEVESO risk assessment in the installation area*
  - *safety devices and external fire calculations*



RFX – INAIL Cooperation Agreement

Operations:

- *The procedures for overall certification of SF6 storage system:*
  - *storage tanks, high pressure plant and self-propelled trolleys used to load the gas in the main plant.*
- *The assessment of the compatibility of the safety systems adopted for the plant manufactured in Germany and that manufactured in Japan.*
- *The notified bodies certification for the storage plant and the loading plant of the SF6.*
- *Some papers from the agreement:*
  - *"The PRIMA Test Facility: SPIDER and MITICA test-beds for ITER neutral beam injectors", New Journal of Physics;*
  - *"Procedure di sicurezza per il Neutral Beam Test Facility", Milano SAFAP 2016 and SAFAP 2018 (update);*
  - *"Elementi di fisica e di ingegneria del Reattore a Fusione", Raccolta n. 1/2017 Ordine Ingegneri Roma;*
  - *"Progress in the ITER Neutral Beam Test Facility", IAEA-FEC 2018 Conference.*

Collaborations of NBTF

CONSORZIO RFX
Ricerca Formazione Innovazione

ENEA

INFN

Max-Planck-Institut für Plasmaphysik
EURATOM Association

KIT
Karlsruhe Institute of Technology

CCFE
CULHAM CENTRE FOR FUSION ENERGY

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

Istituto di Fisica del Plasma "Piero Caldirola"
Consiglio Nazionale delle Ricerche

ICMATE

CNR NANOTEC
INSTITUTE OF NANOTECHNOLOGY

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