Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Lo sviluppo delle tecnologie e il contributo scientifico a livello italiano e regionale

L'ENERGIA NUCLEARE PER LO SVILUPPO SOSTENIBILE. SCENARI POSSIBILI

Mercoledì 4 giugno 2025, at 14:30

Sistema scientifico dell'innovazione del Friuli Venezia Giulia

Alessandro Del Nevo – Responsabile Divisione NUC-ING

Il Dipartimento NUCleare

FUSIONE
Frascati, Brasimone

- Fisica del Plasma & Modeling
- Tecnologie della fusione
- Ingegneria sperimentale
- Neutronica e sicurezza
- DTT

FISSIONE
Bologna, Brasimone, Casaccia

- Generation IV- SMR- AMR: Progettazione e sviluppo tecnologico
- Sicurezza
- Gestione rifiuti radioattivi

SICUREZZA, SALUTE E AMBIENTE
Frascati, Casaccia

- Tecnologie fisiche per
  - Lotta al rischio CBRN-E
  - Protezione dell'ambiente
  - Beni culturali
  - Salute

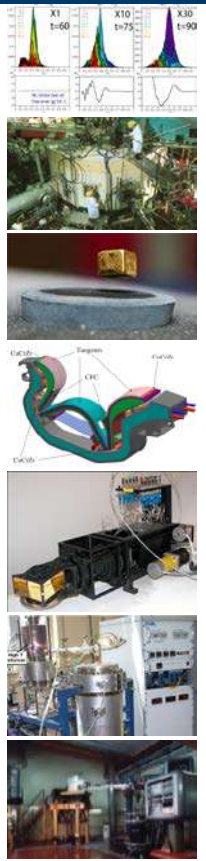
Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti
Casaccia

STAKEHOLDERS

- EURATOM
- IAEA
- OECD-NEA
- Istituzioni internazionali:
  - EU, Russia, Cina, USA, Corea, India
- FUSION for ENERGY
- ITER
- NATO
- Governo Italiano

Development of technologies in the field of Nuclear Fusion

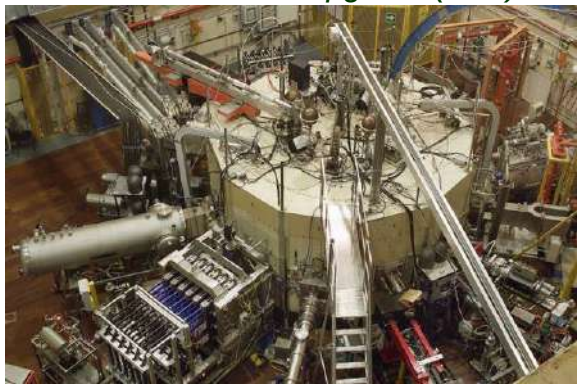
- ENEA has developed in time competences in all areas of fusion physics and technology, and has developed a large fleet of facilities
  - Fusion Theory and Modelling
  - Experimental Physics (FT, FTU → DTT)
  - Design & technological R&D for ITER, DTT, DEMO
  - Superconductivity – Materials, cables, coils
  - Materials (structural, functional)
  - High Heat Flux Technology (materials and components)
  - Blanket technology & Fuel Cycle
  - Neutronics
  - *Remote Maintenance*
  - *Safety*



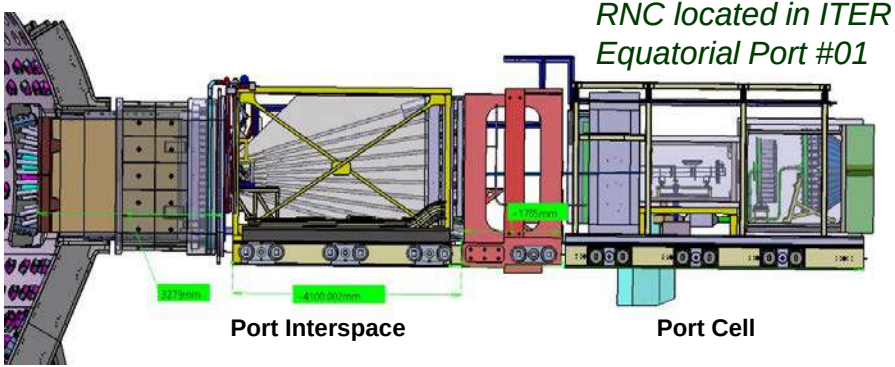
Plasma physics and fusion experiments

- Tokamak **machine operation**: running the FTU machine for 30 years
- Acquisition and development of control systems (CODAS) according to ITER technologies
- Participation in **JET** operation & experiments
- Development of **DTT CODAS system**
- Development of **DTT diagnostics**
  - Magnetic diagnostics
  - High res saddle coil array for MHD analysis
- **Neutron camera** for **ITER:** ENEA coordinates the EU team in charge of design (2014-2024)

Frascati Tokamak Upgrade (FTU)

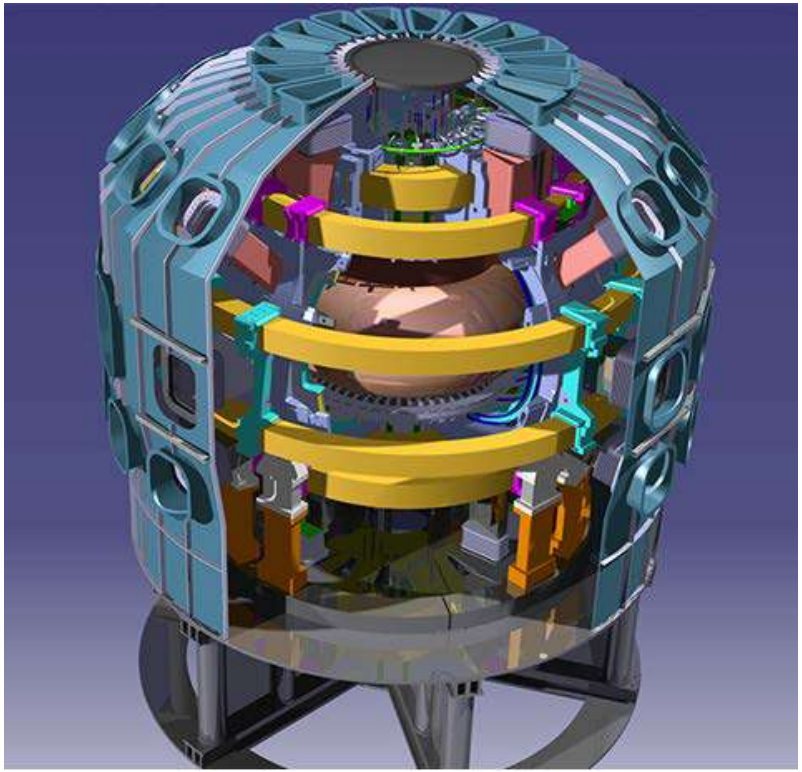


RNC located in ITER Equatorial Port #01



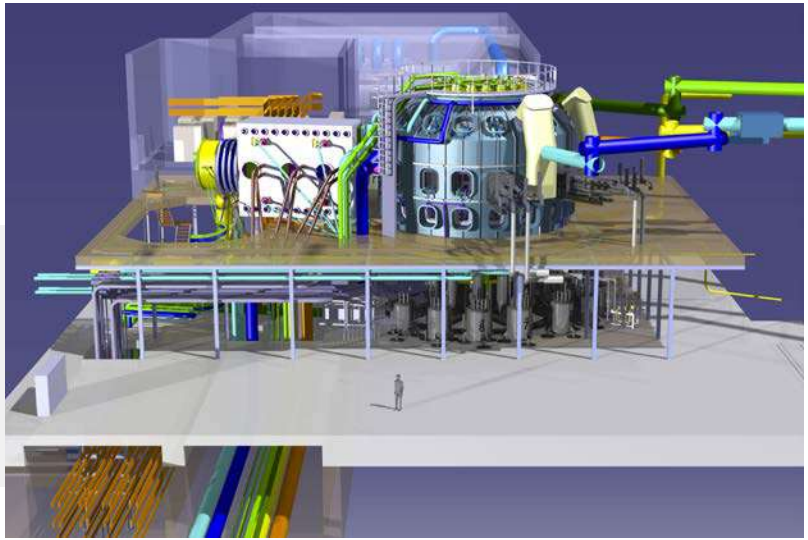
Divertor Tokamak Test facility (DTT)

- DTT – a new, fully superconducting tokamak being built at the Frascati research center
  - Largest nuclear fusion facility under construction in Europe after ITER
  - Its mission is to provide an integrated fusion environment to test power exhaust strategies useful for the first nuclear fusion power plant
  - Plasma current up to 5.5 MA, toroidal magnetic field 6 T at the plasma center makes DTT in a position relevant for the present DEMO design



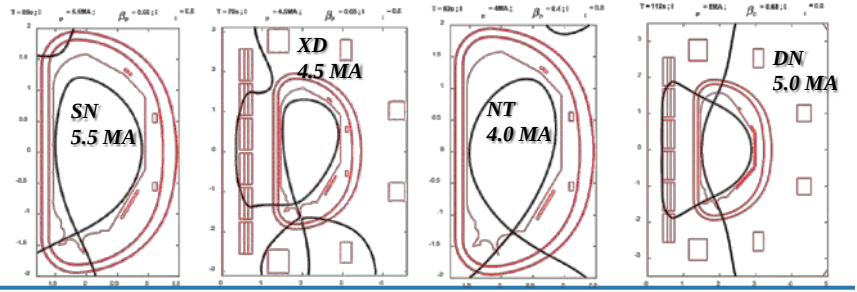
Divertor Tokamak Test facility (DTT)

- 6 Polodal field Coils: 4 NbTi / 2 Nb_3Sn
- Central solenoid: 6 Nb_3Sn
- Toroidal Field Coils: 18 Nb3Sn coils



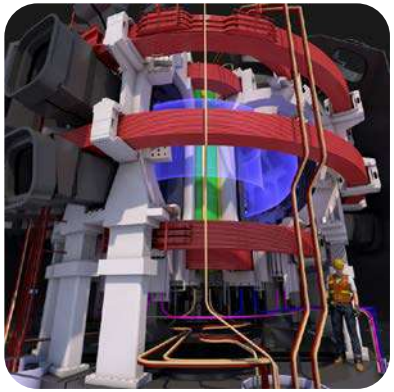
- **Additional heating power 45 MW**
  - ✓ ECRH 16MW 1st phase → 32MW 2ndphase
  - ✓ ICRH 4MW 1st phase
  - ✓ NBI 10MW 500keV (on hold)

- **Largest possible flexibility in terms of:**
  - **Completeness of plasma scenarios**
  - **Space allocated for divertor**
  - **Power density on divertor**
  - **Mix of additional heating systems**



Superconductivity

- R&D on materials and design of SC cables & magnets
  - Design and manufacturing of high current conductors and cables for large coils for ITER, DEMO
- Design of the whole DTT SC magnet system
  - 18 Nb_3Sn Toroidal Field coils (42.5kA, 11.9T)
  - 6 Nb_3Sn & NbTi Poloidal Field coils (28.5kA, 9.2T)
  - 6 Nb_3Sn Central Solenoid modules (31.3kA, 13.6T)
  - Set of SC feeders and SC current leads
- HTS tapes development and LTS strands characterization
  - Pulsed Laser Deposition YBCO tapes R&D
  - HTS tapes characterization (AC/DC tests, X-rays, SEM&ATM microscopy)
  - HTS cables design, prototyping and test
  - Nb_3Sn/NbTi wires DC/AC characterization
- FCCTF (Frascati Coil Cold Test Facility)



Plasma facing materials & components

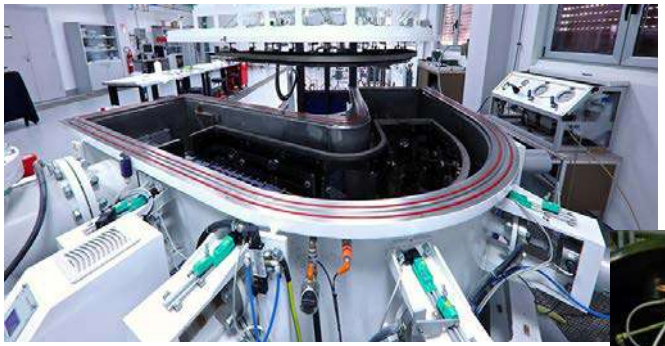
PFC material characterization

Development of junction technology

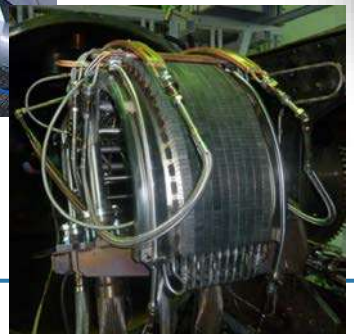
- Diffusion bonding (Hot Radial Pressing)
- Brazing

Applications:

ITER vertical target prototypes
PFU manufacturing process qualify for the IVT production

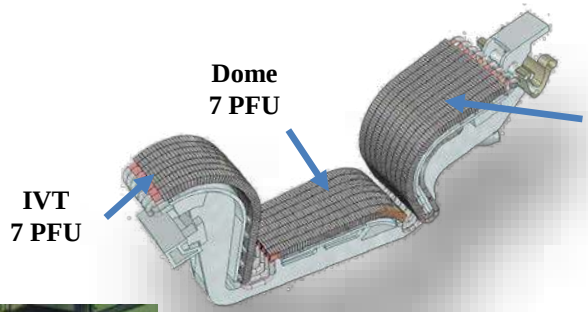


ENEA patent oven for the manufacturing of the Plasma Facing Units of the ITER Inner Vertical Target



ITER IVT PFU successfully tested @10 MW/m^2/5000 cycles, @20 MW/m^2/500 cycles.

DTT Divertor design and manufacturing



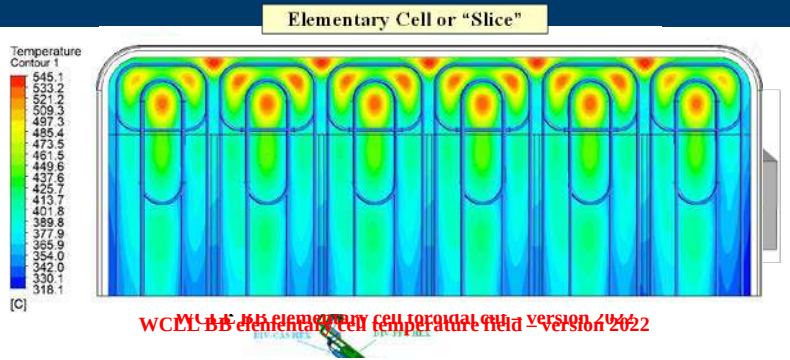
First **DTT divertor target** prototypes for HHF testing and critical flow verification

Blanket technologies & Balance of Plant

Water Cooled Lithium Lead Breeding Blanked is featured
- Water coolant @ 295 – 328 °C @ 15.5 MPa
- PbLi as breeder, n-multiplier and T carrier

Areas of research – BB and BoP

- Design and analyses activities. *CAD, Integration, System engineer, Neutroncs, Thermal and Thermo-hydraulics, Magneto-hydrodynamics, Thermo-mechanics, Safety studies, etc. Samples:*
  - Modelling of PbLi flow in BZ and manifold under magnetic field
  - EXP and numerical studies of water/steam-PbLi reaction in accidental scenarios
  - Addressing the dynamic behavior of the system in different operative states
- R&D activities. *PbLi technologies, T technologies, Water coolant technologies, etc. Samples:*
  - Set-up of basic experiments for investigating thermophysical and chemical proprieties of PbLi, T permeation, T solubility in PbLi, etc.
  - Design, manufacturing and testing of first of a kind demonstrators, such as extractor, purification systems, prototypical sensors, etc.



WCLL BB elementary cell toroidal cut – version 2022

WCLL BB Balance of Plant CAD – version 2020

Prototypical Tritium Extractor – Permeator Against Vacuum

Blanket Technologies –EXP infrastructures

❑ TRITIUM EXTRACTION FROM LiPb

- **PERI II** Characterization of PRF of material and coating in the temperature range between 200 and 700 °C with hydrogen and deuterium
- **TRIEX II** Characterization of technologies for the extraction of H or D from LiPb (GLC, PAV)
- **Hyper Quarch II** Hydrogen Permeation Quartz Chamber measure the tritium solubility and diffusivity in LLE in the range of temperature 300–550 °C

❑ LiPb Technologies development

- **IELLLO** Instrumentation development and characterization in LiPb (Pressure transducers, mass flow meter, level sensor)
- **LIFUS5/Mod3** Separate effect test facility for investigation of water-LiPb interaction
- **THALLIUM** HCLL in-TBM imbox LOCA simulated the rupture of the stiffening plate of the HCLL TBM and the resulting injection of He from the helium cooling system

PERI II facility

TRIEX II facility

Hyper Quarch II facility

IELLLLO facility

LIFUS5/Mod.3 facility

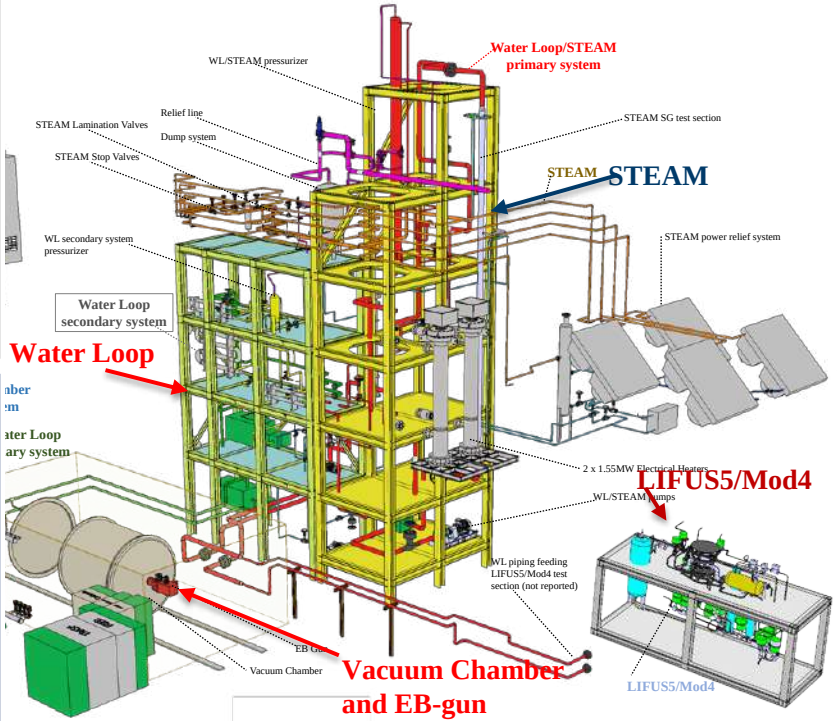
THALLIUM facility

BLANKET TECHNOLOGIES – New EXP infrastructures

- **W-HYDRA** *(Water cooled lithium lead-thermal-HYDRAulic)* **platform includes***:*
  - **WL** (*Water Loop*): WCLL Test Bed and a related water facility (Medium/Large Scale Water Facility)
  - **STEAM** (*STEAM generator test facility*)
  - **LIFUS5/Mod4** (*the 4° version of lead-LIthium FUSion 5 facility*) → integral test facility experiment of PbLi/water reaction scenarios

W-HYDRA is a large experimental infrastructure (25m in height, 3 MW heating power, 18.5 MPa pressure)

- Strategic for the development of the TBM, the Breeding Blanket and the Balance of Plant of the ITER and DEMO reactors
- Unique in the international panorama, it will be able to support the design, technology and licensing of ITER's Water Cooled Lithium Lead TBS
- Flexible: it can be used for testing activities related to the Fusion field and beyond, thanks to the availability of an 800kW Electron Beam Gun and of a 25 m^3vacuum chamber.



4MW transformer and electrical cabin

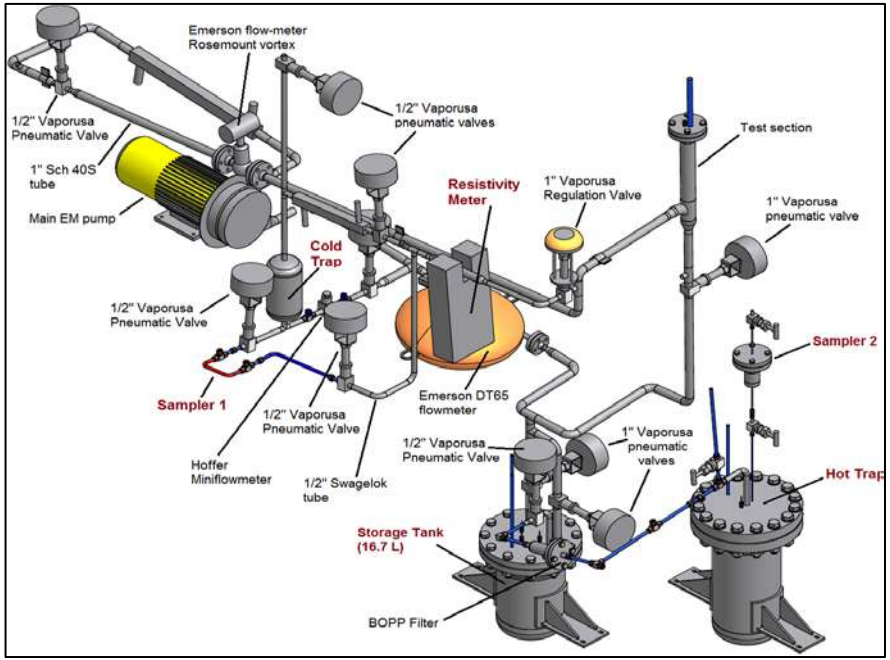
W-HYDRA platform under construction – available @ ENEA C.R. Brasimone by 2025

LIFUS 6 : Only liquid lithium facility in Europe

LIFUS 6: to support the development and costruction of the DONES irradiation facility (in Spain)

LIFUS 6 plant is essentially constituted of two different loops, mounted on a steel frame:

- the main loop (isotherm), where Lithium flows at a maximum flow rate of 30 L/min and the max temperature of 350°C, which houses the Test Section; Lithium can reach the maximum speed of 15m/s on the specimens surface.
- the secondary loop, where Lithium flows at ~ 0.3 L/min and which houses:
  - the Cold Trap (200-210°C), devoted to the online purification of Lithium from non metals impurities like Carbon, Oxygen and Hydrogen;
  - the Resistivity Meter, able to online monitor the total concentration of the impurities solved in Lithium;
  - a small volume (~ 25 mL) Lithium sampler.



The plant is additionally equipped with an Hot Trap, set outside the loop and directly linked to the Storage Tank, where all the Lithium inventory can be statically kept at 550-600°C for long time, in order to be purified from Nitrogen.

Technologies of Materials

- Materials for Fusion (TBM, DEMO)
  - Development of low activation F/M steels resistant to low temperature neutron radiation (DBTT shift, He embrittlement)
  - Anti permeation / corrosion coatings
  - Design and characterization (mechanical, microstructural, corrosion in PbLi, 3H permeation)
  - Mechanical qualification tests of Eurofer 97 in accordance with RCC-MR
  - PbLi technologies – corrosion of materials, development of 3H sensors, Getter-based purification systems
  - Corrosion in radiolitic water

BID1 pool facility

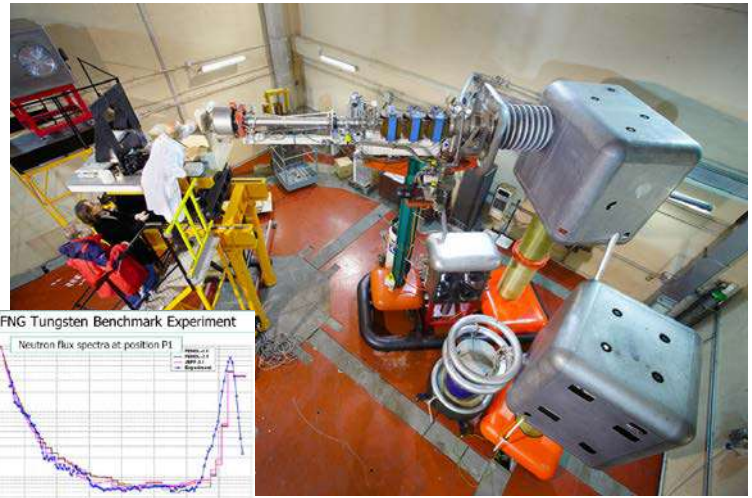
LIFUS 6 molten Li loop

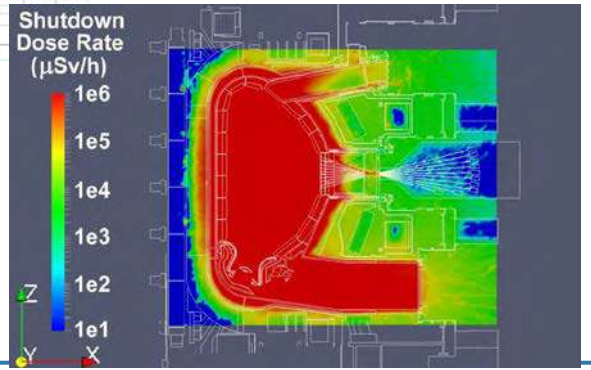
RACHEL LAB.
Reactions and Advanced CHEmistry of Lead

GIORDI Fretting equipment

Experimental and Numerical Fusion Neutronics

- **Frascati Neutron Generator (FNG)**
  14 MeV neutron source of medium intensity (10^{11} n/s)
  - Validation of nuclear data for fusion
  - Validation of ITER components nuclear design
  - Tests of radiation hardness
  - Detectors' calibration and characterization





✓ Benchmark experiments (FNG, JET)

✓ Develpment of advanced codes for radiation transport/activation/doserate calculations, and validation (JET, ITER, DEMO, DTT)

SORGENTINA-RF Project

Project goal: Increase the Technology Readiness Level (TRL) of an experimental plant for the production of radiopharmaceuticals using fast fusion neutrons (target: TRL7)

Total project cost: € 4’664’014.45

- € 3’498’010.84 **Regione Emilia Romagna**
- € 1’166’033.61 **ENEA**

Project outlook:

- ❑ Waste-minimized production of radiopharmaceuticals
- ❑ Low-cost production of parent solutions for radiopharmaceuticals
- ❑ Development of new technologies in collaboration with industry

Conclusions

- ENEA has developed in time competences in all areas of fusion physics and technology, and has developed a large fleet of facilities
- ENEA is now the 2nd contributor to the EU fusion programme
- It has provided key contributions to ITER design and construction and is developing key technologies for fusion demostrations/prototypes
- The collaboration with industry has resulted in about 2 B€ contracts awarded to Italian industries for the manufacturing of ITER components
- ENEA is now the major contributor to DTT – the new Italian experiment in support of EU fusion roadmap

Italian fusion network (ENEA Beneficiary)
of research on fusion includes over twenty partners among universities, research bodies and industries coordinated by ENEA.
More than 700 scientists are involved.

Thank you
for your kind attention!

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