T-chamber at AGHS

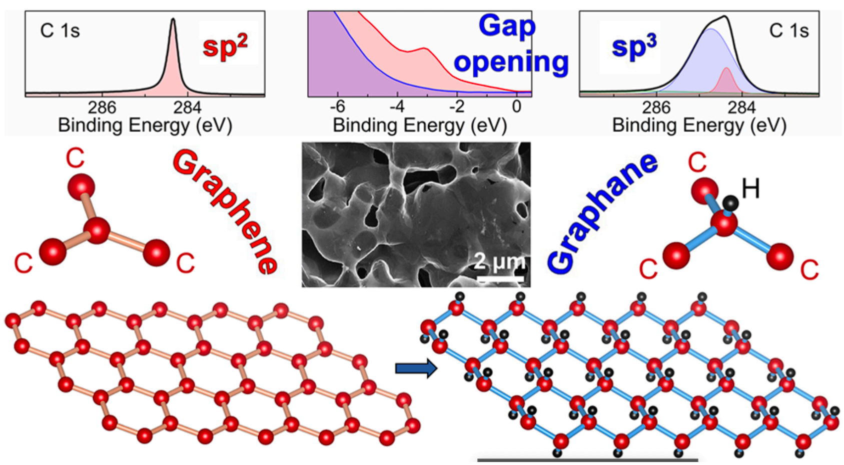
Gianluca Cavoto - Sapienza and INFN Roma

July 2025

Demonstration of graphene hydrogenation

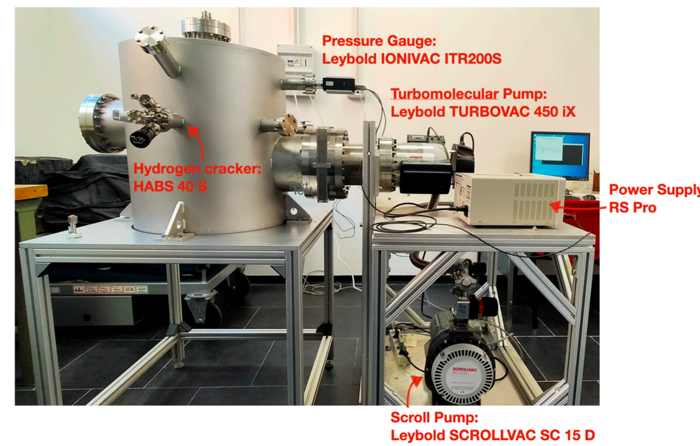
Gap Opening in Double-Sided Highly Hydrogenated Free-Standing Graphene

M.G.Betti et al. Nano Lett. 2022, 22, 7, 2971–2977



T-chamber

Financed by Princeton U.



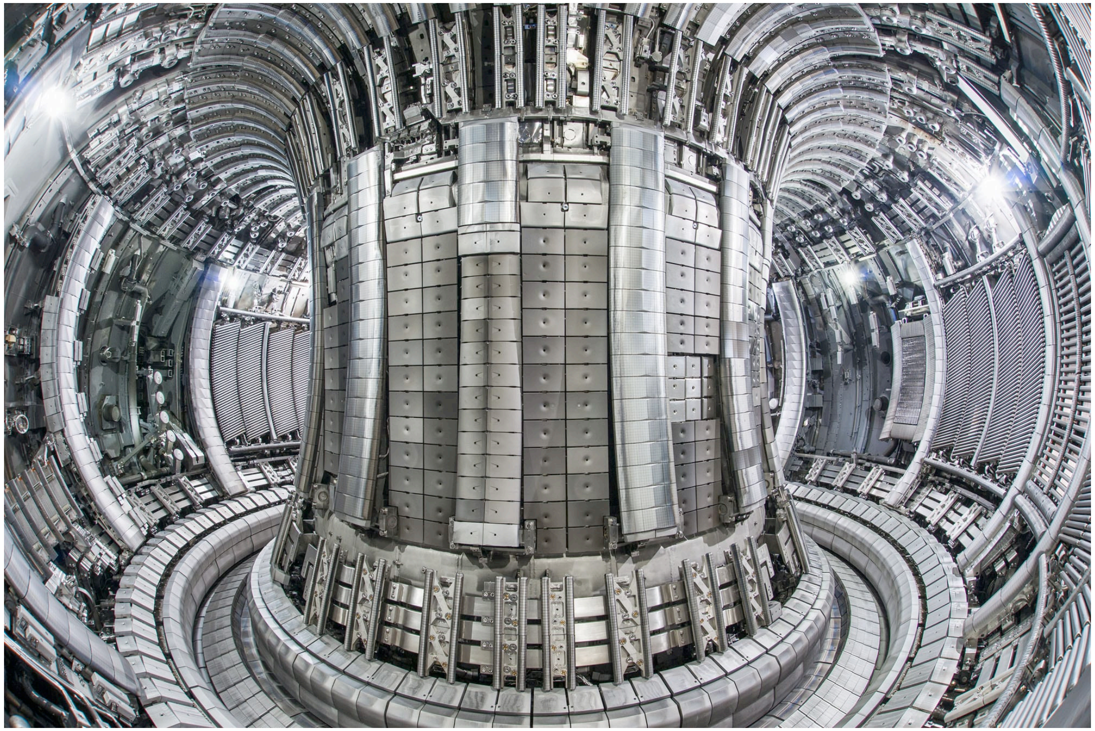
Use thermal cracking in vacuum

Hydrogen and deuterium share the **same chemistry** with tritium

Port the graphene hydrogenation technique
to **tritium storage on** carbon nanostructure

JET Tokamak at Culham Science Center

- https://ccfe.ukaea.uk/ : Culham Center for Fusion Energy
- (Former) European site to study fusion

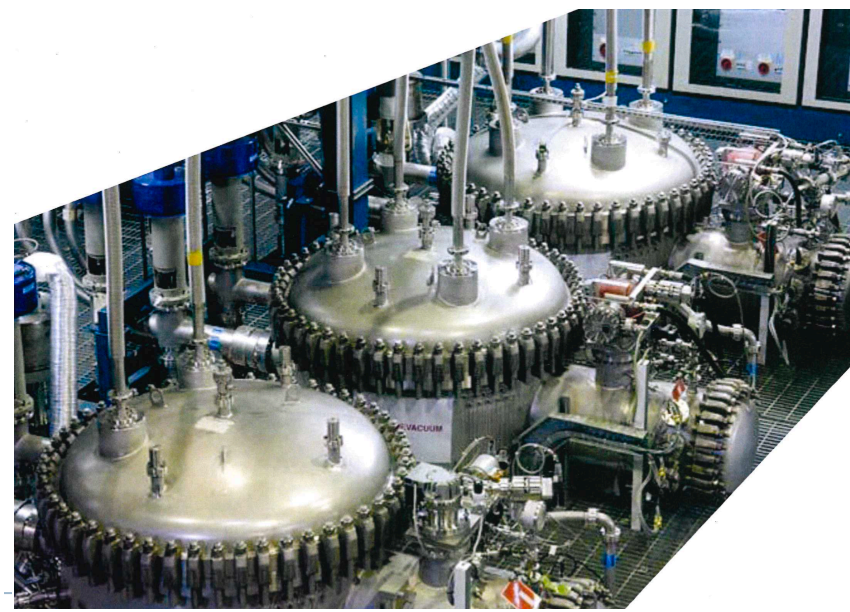


Close to Oxford
I visited the facility last year

They are currently maintaining a 10 g inventory of tritium (eventually we would need 1-10 μg for a Phase1 experiment)

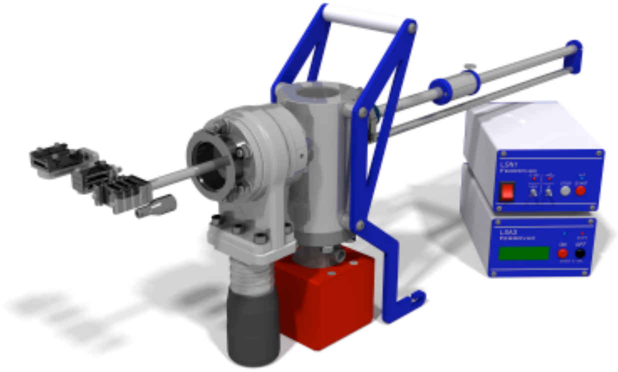
AGHS

- **JET** stopped operation recently (D-T reaction)
  - Now in a decommissioning phase
- The UKAEA's **Active Gas Handling System** (**AGHS**) is the facility they operated at Culham to handle tritium for JET
  - An entire building quite busy for a variety of operation:
  - Confinement by containment
  - Impurity processing
  - Isotope separation
  - Storage and supply
  - Gas and **Water** detritiation



When not in use, tritium sits in depleted Ur beds

Tritium on graphene: technology constraints



- Smaller T-chamber and a **handling system for the sample**
- The tritiated graphene should be **extracted** from T-chamber and **kept in vacuum (special suitcase)**

Milestone of Phase 0: feasibility study

- We are currently **buying** from UK AEA the **service** of a feasibility study of the porting of our technique to tritium at their site.

1. The tritium compatibility of the design of the Ptolemy sample preparation system (including
   the primary vacuum chamber and cracker)
2. Viability of integrating into our tritium subsystems in the vacuum conditions and timeframe
   required by the Ptolemy Project.
3. Investigating the regulatory landscape and export possibilities to ensure tritium is appropriately handled and shipped in accordance with international requirements.

UK Atomic
Energy
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A **four month project** (we need to meet them to specify requirements and to provide details - flow, contaminants, residual gas analysis, …)

INFN and UK AEA recently signed an NDA to protect Intellectual property.

Outlook

- We plan to have clear statement of the **feasibility** of the project quite soon (beginning of 2026)
- We will then invest some time to **optimise the design** of the vacuum T-chamber to be used at AGHS
- Resources to actually build and operate the chamber during Phase-1to be found by the Ptolemy collaboration
- Tritium available for the Ptolemy demostrator after a while the start of Phase-1 (to be detailed in the CDR)

Back up slides

Steps towards tritium on graphene

- Evaluating the access to tritium at UK atomic agency authority.
- Need various steps
  - 1) design of a new smaller T-chamber to be located into a glove box (optimise gas flow, reduce contaminants, check parts are compliant with tritium usage…)
  - 2) manipulation of the sample in vacuum
  - 3) shipping (in vacuum) according to regulations
  - 4) assessment of the level of radioactivity with standard metrology
  - 5) first test in a vacuum chamber (beta spectrum, C 1S, …)

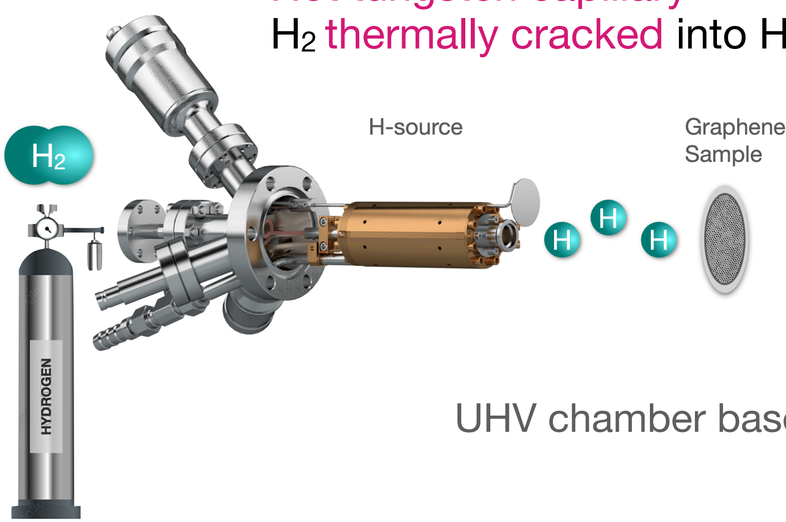
Goals

- Have a **< 1 GBq solid atomic tritium** target
  - Less troubles with radio safety regulations
- Use carbon nanostructure as support
  - Well defined **position** in the apparatus, well defined **potential**
- Demonstrate the solid target is **stable** (i.e. no tritium release) at **room temperature**
  - To be certified according to radio-protection standards
- **Measure**
  - Radioactivity **activity**
  - band gap, resistivity
- First **beta spectrum** measurement

Concept for graphene target production

- Use **thermal cracking** (2400 K) of hydrogen molecule
  - Atomic thermal hydrogen flowing onto the sample with a thermal kinetic energy

Atomic Hydrogen source
Hot tungsten capillary
H_2 thermally cracked into H



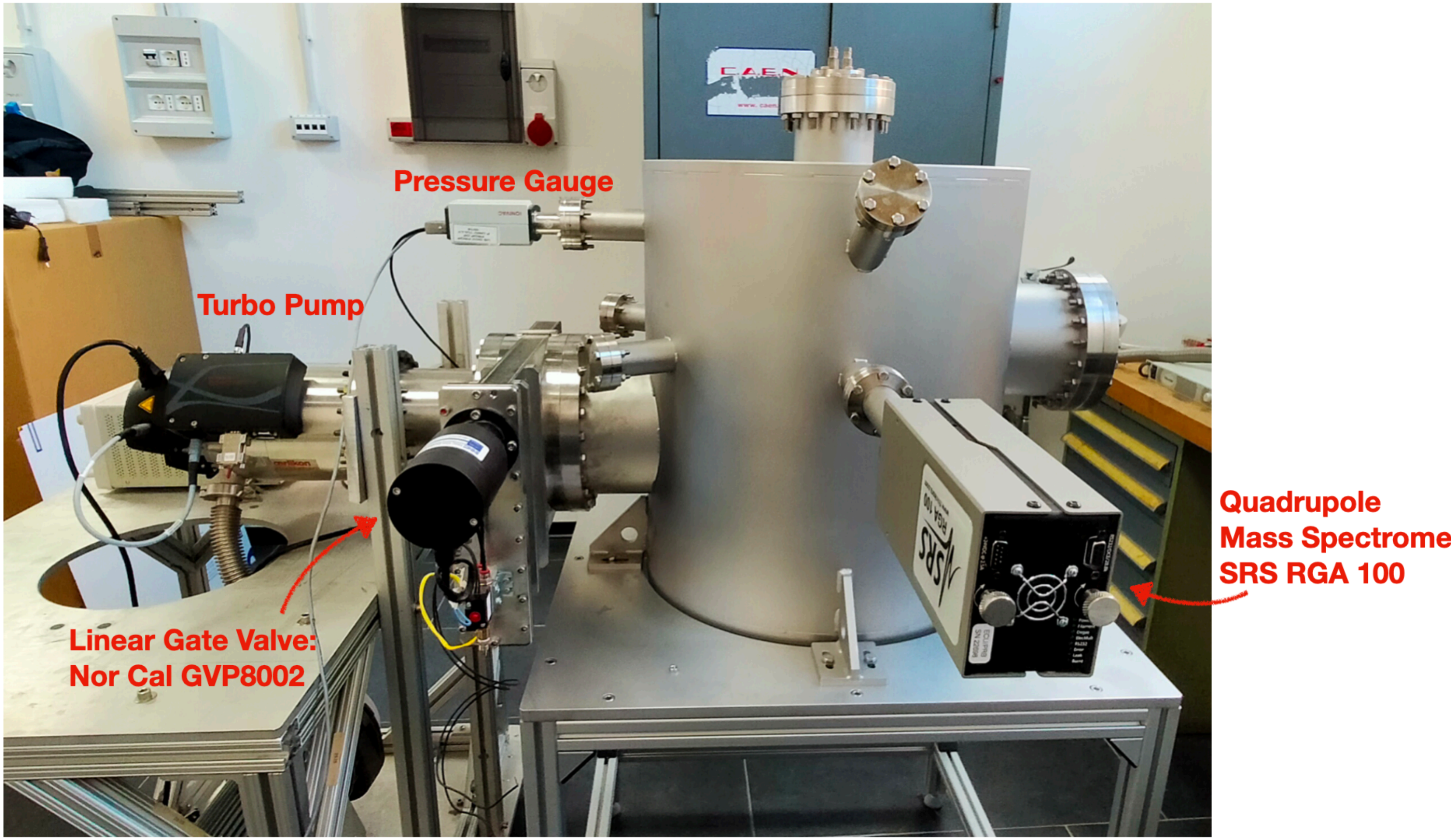
Mass Spectrometer
In order to measure H_2 flux
And to control possible contaminations

UHV chamber base pressure goal: 10^{-10} - 10^{-9} mbar

Using **commercial components** (reproduced in several experiments now in Roma and RomaTre)

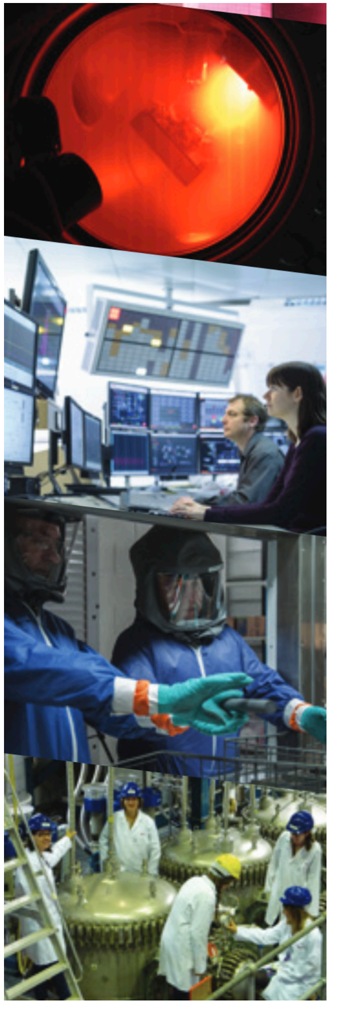
T-chamber at Sapienza - right view

Financed by Princeton U.



H3AT (heat) at Culham Science center

- From their official brochure:
  - The Hydrogen - 3 Advanced Technology centre (H3AT) will provide
    - opportunity for **academia**, industry and partners to benefit from
      - the tritium technology centre (**infrastructure** to handle tritium)
      - The high level of **technical expertise** (training and **R&D**)



*A flexible suite of **enclosures** designed to enable a wide variety of experimental work, including: **pure tritium science**, **process development**, component testing and waste detritiation*

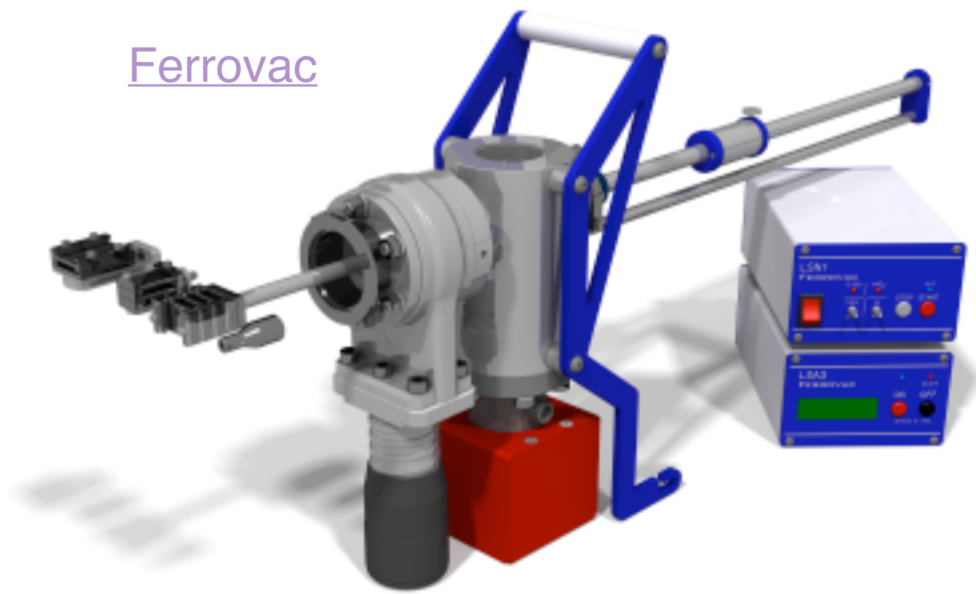
Laboratory for H3AT still in construction
Apparently interested to collaborate to our project of tritium on graphene
But
H3AT is a medium term project (AGHS is in fact in another building now…)

Shipping of the sample

- There are clearly legal issues (tritium inventory, etc.) but they can be overcome
- Technically: we need a special <u>suitcase</u> to ship a sample to be kept in vacuum

Ferrovac

NB: AGHS bought tritium from Canada reactors: shipped in depleted Ur beds



First test in Italy

- Contact with **ENEA INMRI**
  - Still interested in evaluating radioactivity and stability with standard radio-metrology procedures

- A legal statement on the stability of the radioactive source might be obtained.

- One relevant different with hydrogen: tritium can induce **radiolysis** of the substrate
  - β particles can release energy in the graphene and break chemical bonding (graphene get damaged, other T atoms get released…?)
  - **Simulation of energy loss** needed

Beware of water

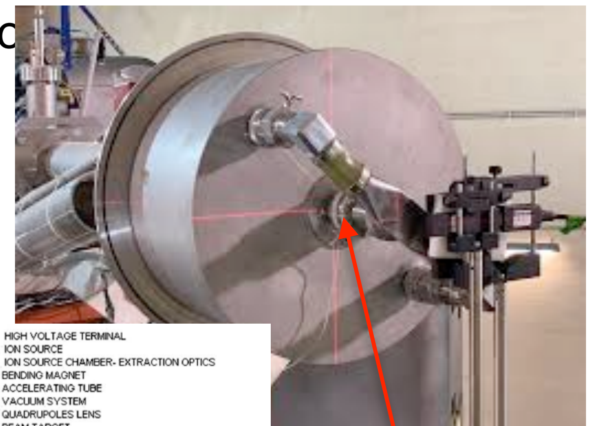
- Presence of water or oxygen can induce the formation of tritiated water (**HTO**)
  - Extremely dangerous (corrosion due to radiolysis)
  - Need to have clean samples (thermal annealing)

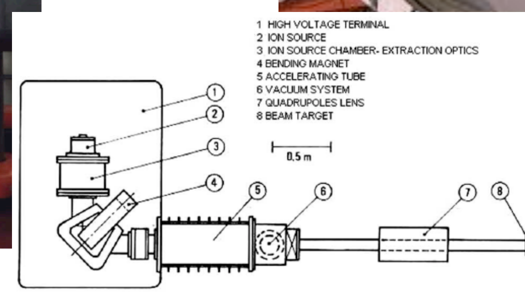
- Formation of other compound must be evaluated
 (i.e. triated methane CH_3T)

We should study the **residual gas** after **deuteration** in our current T-chamber : D as a proxy of T in the chemical reaction inside the T-chamber

Where “solid” tritium is used in Italy

- ENEA FNG (**F**rascati **N**eutron **G**enerator)
  - ENEA Frascati where the ITER DTT (*divertor* demonstrator) will be built
  - Tritium **beam target** (D +T reaction to yield neutrons)
  - Bought from a French company (metal “tritide”)
- Tritiated graphene will be like tritium abso





Beam target

The whole vacuum chamber of the FNG is connected to a tritium detection system
Beam target kept in a glove box
Exhaust sent to atmosphere