T-chamber at AGHS

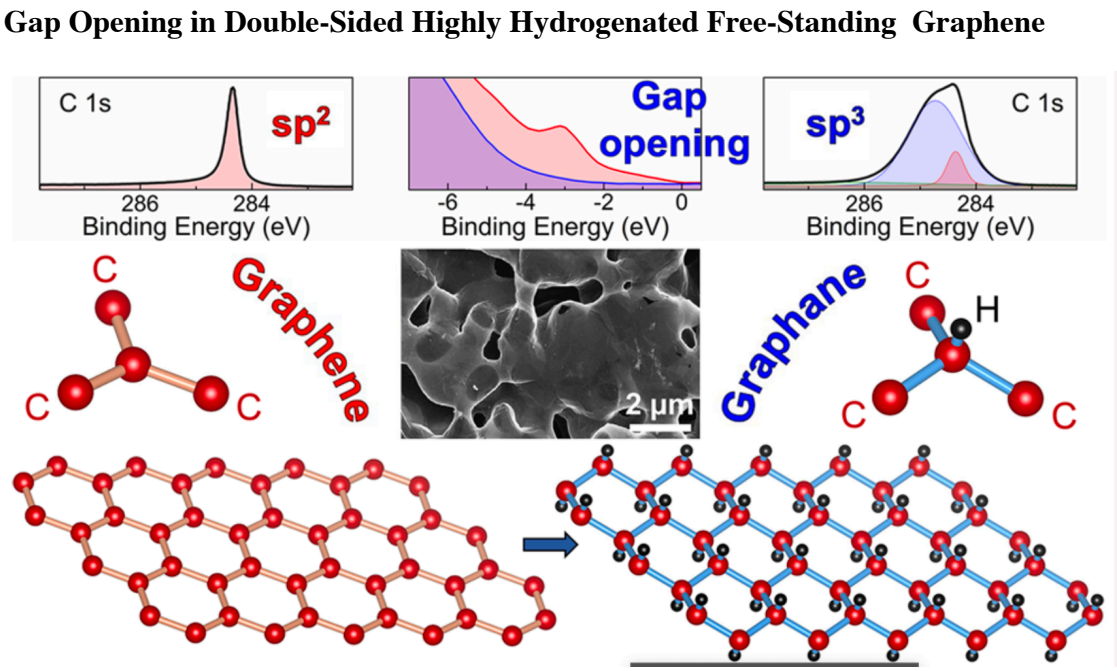
Gianluca Cavoto - Sapienza and INFN Roma

Ptolemy meeting in Genova

Nov 2024

Demonstration of graphene hydrogenation

- Use thermal cracking in vacuum



- Nanoporous graphene (NPG) as substrate
- X-ray spectroscopy to see **sp³** bonds to measure hydrogen uptake

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

Tritium on graphene

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

(Still interesting in future do some spectroscopy on graphene-tritium system)

Port the graphene hydrogenation technique
to **tritium storage on graphene**
(and other carbon nanostructure in future)

Start with **NPG** since self-standing and
proved to allow large uptake

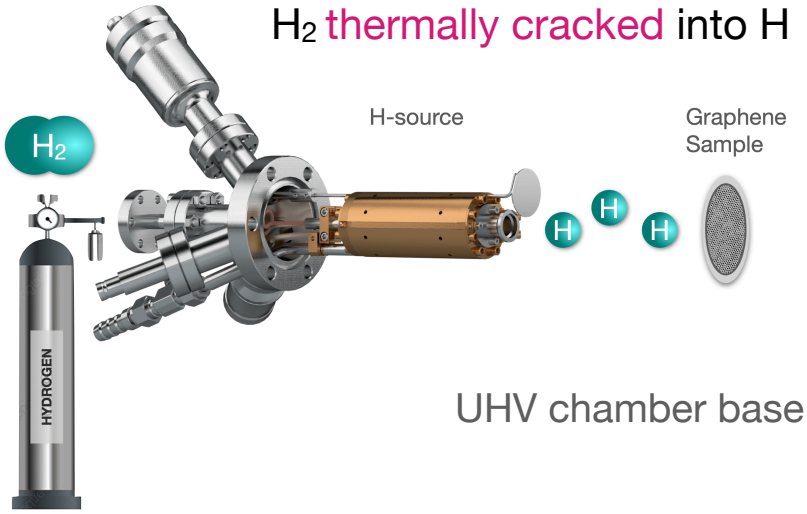
Goals

- 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



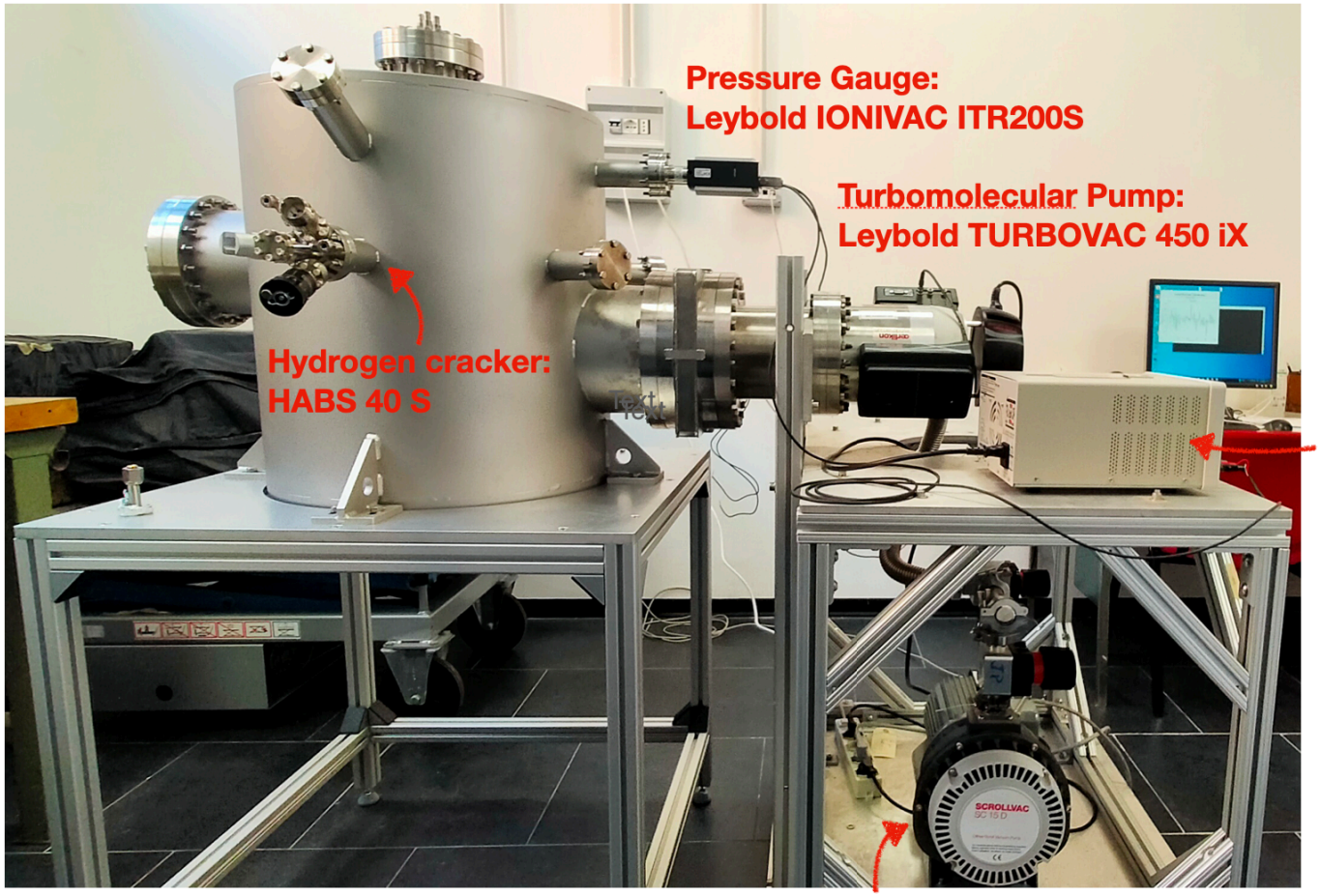
Mass Spectrometer
In order to measure H_2 flux
And to control possible contaminations

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

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

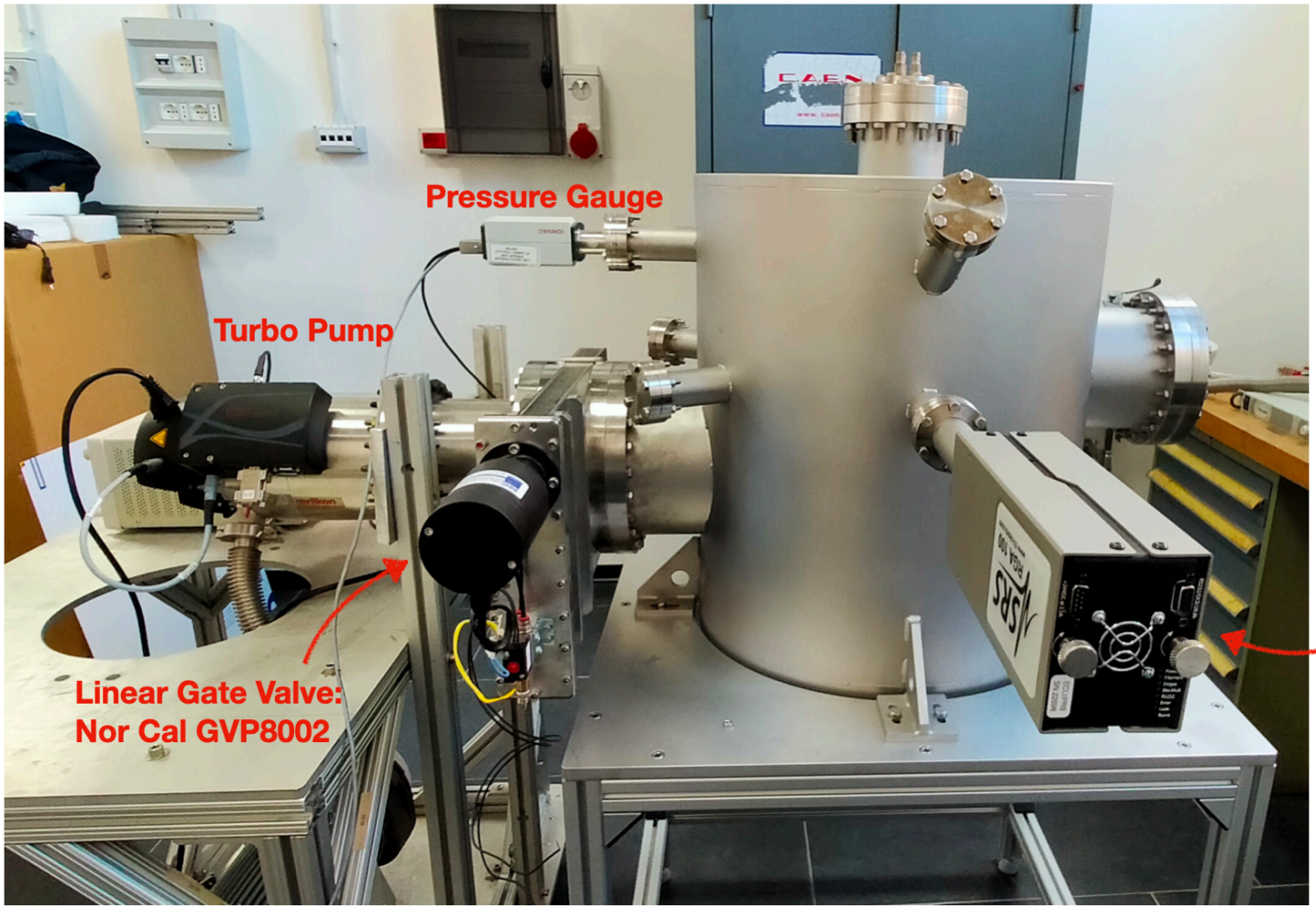
T-chamber at Sapienza

Financed by Princeton U.



T-chamber at Sapienza - right view

Financed by Princeton U.

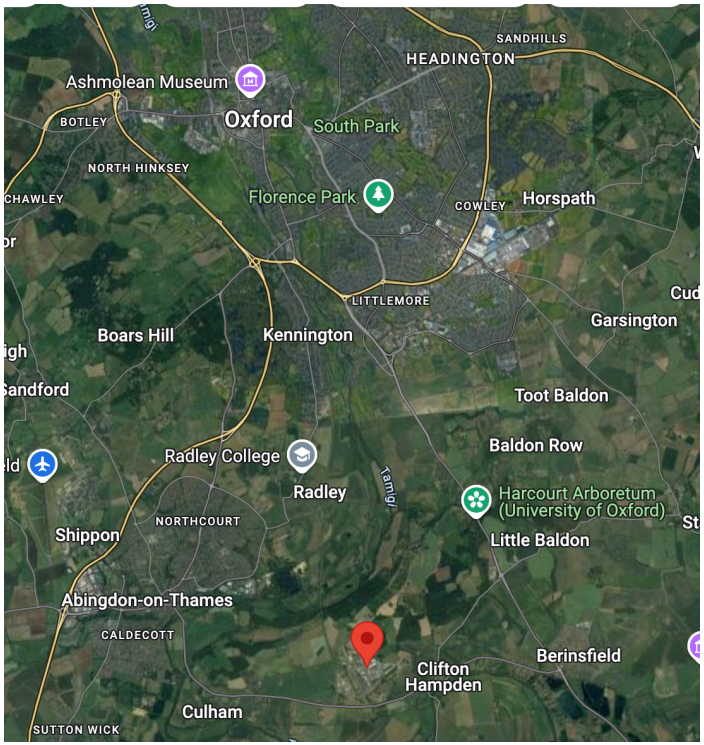


- *Currently working on operating T-chamber at Sapienza*
  - *Optimize deuterium deposition (flow, pressure, position of the sample)*
  - *Characterise exhaust gas (deuterated water ?)*

- **How can we get tritium ?**

Culham Science Center (UK)

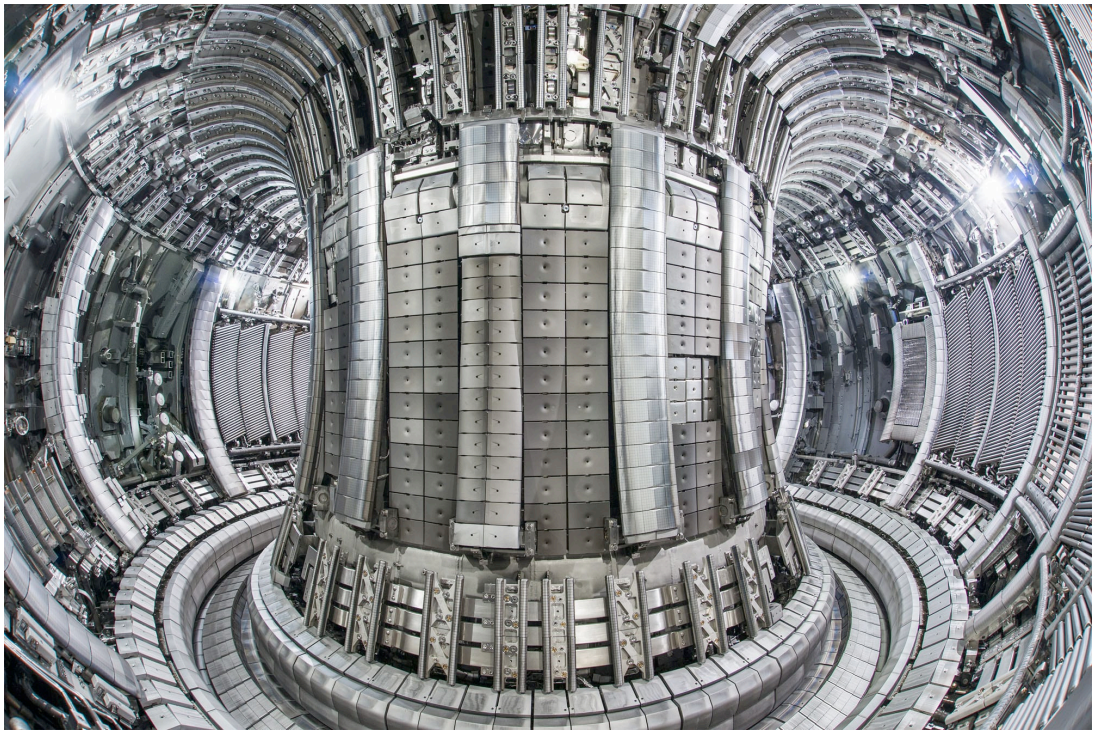
- **Close to Oxford (UK)**



Tritium is here

JET Tokamak at Culham

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

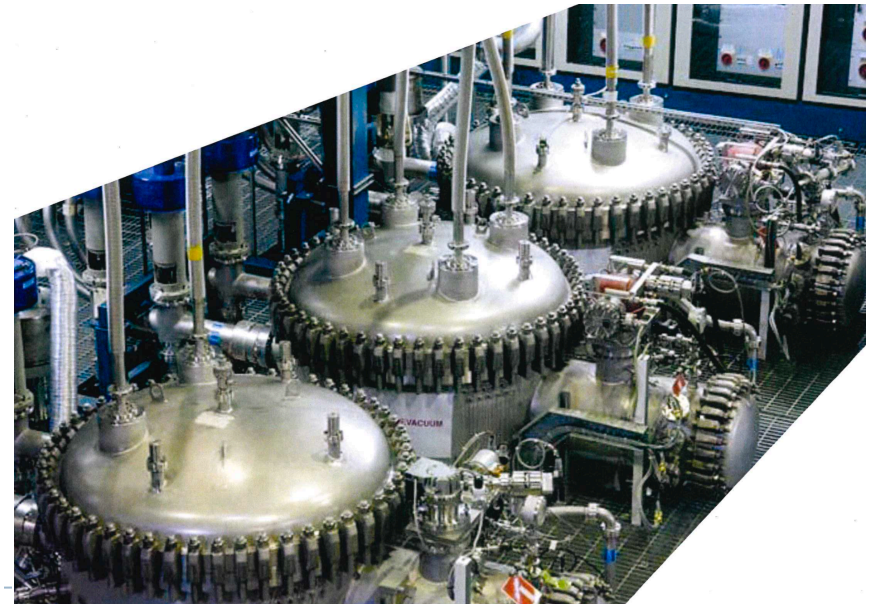


I visited the facility on Sep 20th (one day "course" on tritium handling)

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
  - A 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



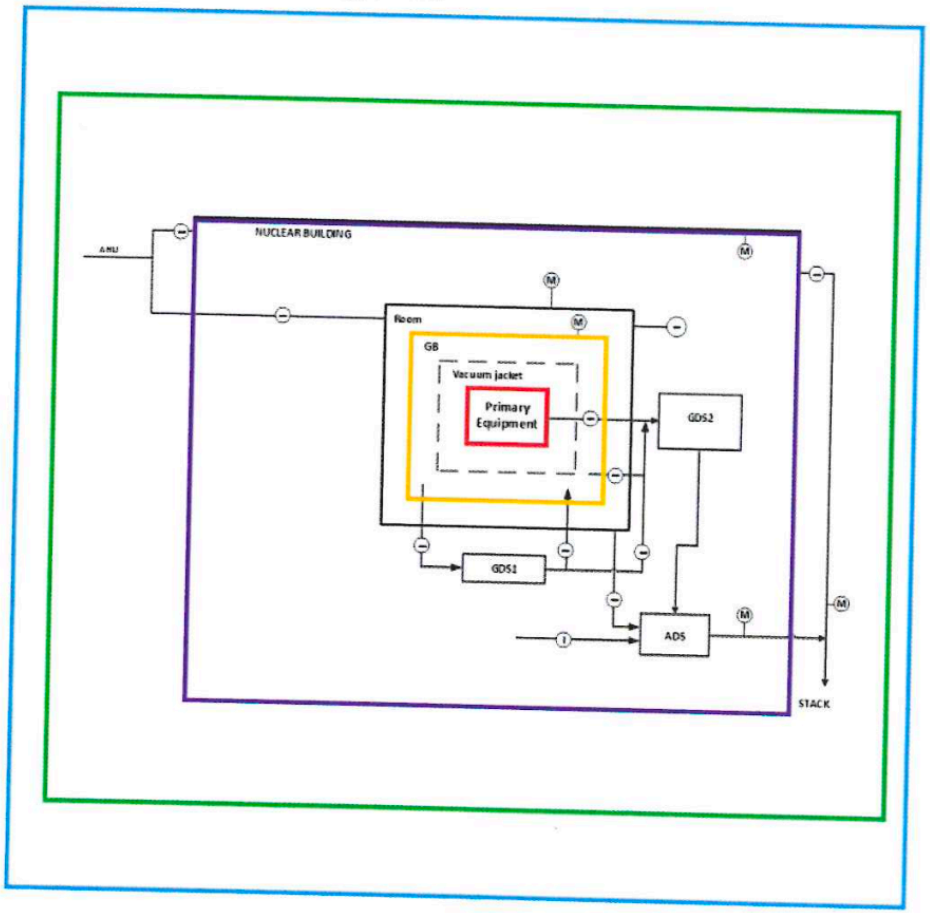
H3AT (heat)

- 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…)

Principle of containment



Primary Containment – process volumes

Secondary Containment – recovery systems

Tertiary Containment – building & radiation workers

Site Boundary – site workers

Environment – general public

T-chamber (may be smaller?)

Glove box to contain T-chamber

- AGHS provides the **inlet** and **outlet** gas pipe for tritium (and all the infrastructure for handling)
  Space in the current AGHS building

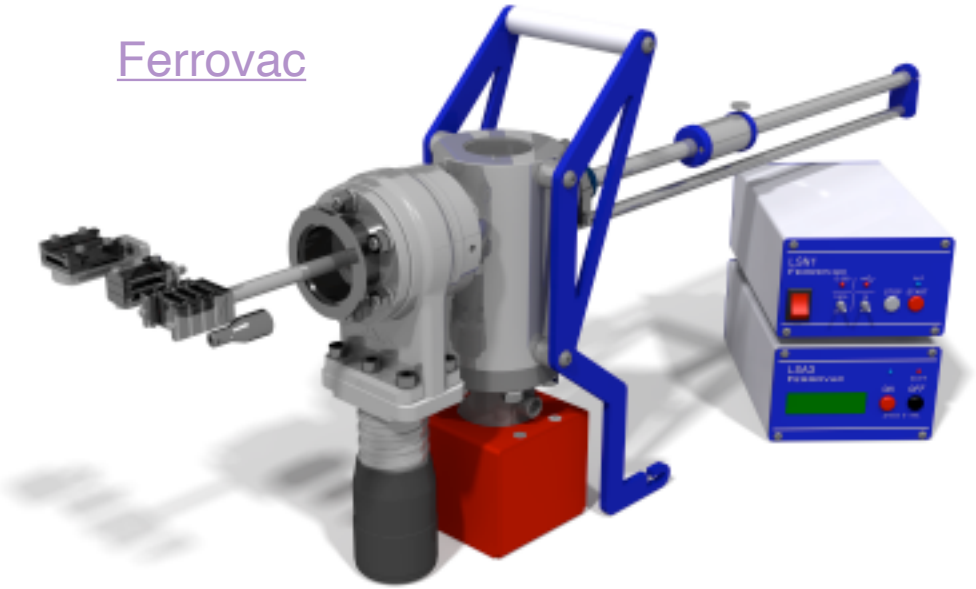
Glove box

- Likely much smaller but should contain T-chamber and pumps and a **handling system for the sample**
- The tritiated graphene should be **extracted** from T-chamber and **kept in vacuum**

Shipping of the sample

- There are clearly legal issues (tritium inventory, etc.) but they can be overcome
- Technically: we need a special suitcase 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

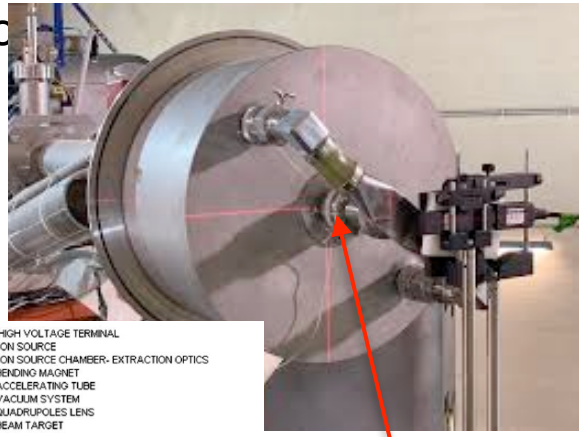
- Presence of water or oxygen can induce the formation of tritiated water (**HTO**)
  - Extremely dangerous (corrosion due to radiolysis)
  - Need to have clean samples (thermal annealing)

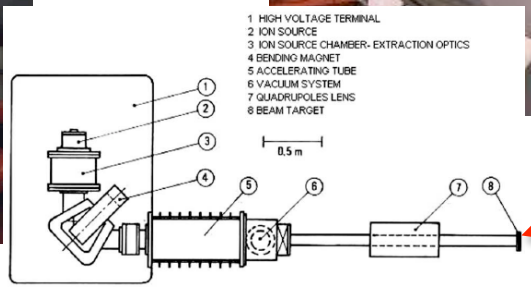
- Formation of other compound must be evaluated
  (i.e. triated methane CH_3T)

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 absc





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

Outlook

- Accessing tritium at UK atomic agency authority not impossible.
- 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…)
    - Contract with AGHS engineers.
  - 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, …)

Likely to be a project over few years

Require additional funding

Tritiated graphene might be available for Ptolemy demonstrator towards the end of the commissioning/operation phase