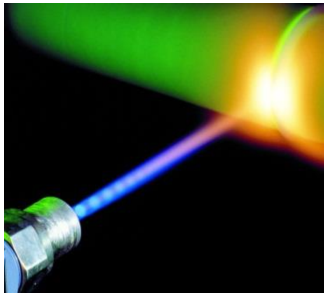
DE LA RECHERCHE À L'INDUSTRIE

cea

www.cea.fr

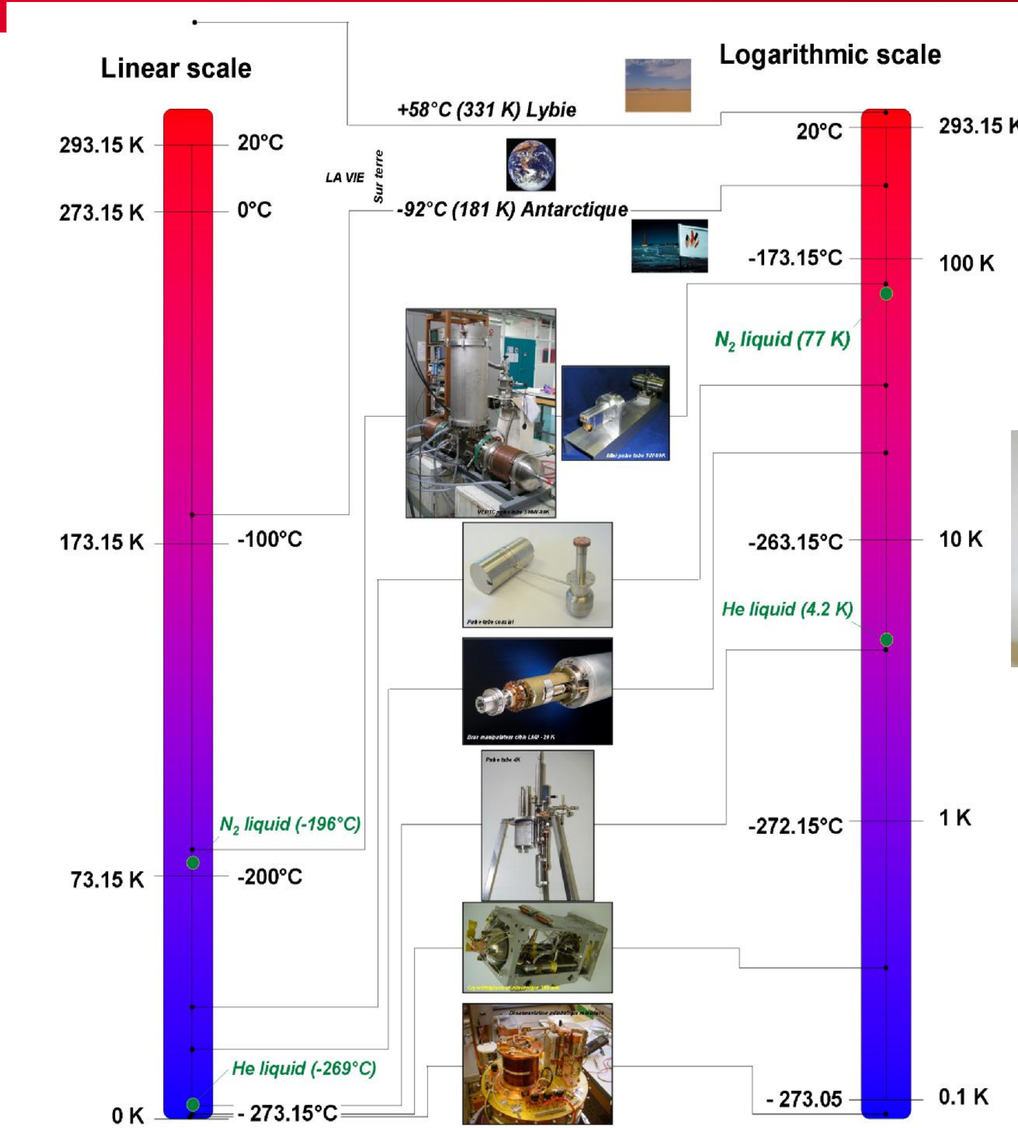
CRYOGENICS FOR HYDROGEN OR DEUTERIUM SOLID TARGETS

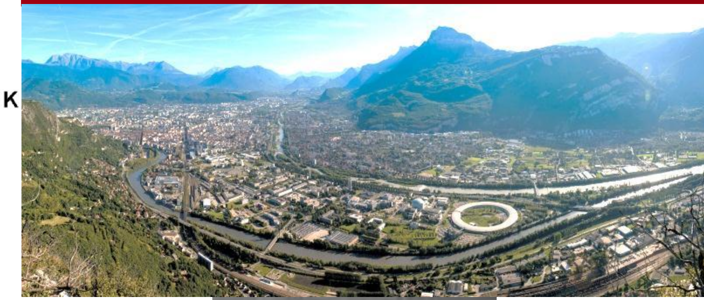


Targetry Workshop 9th -11th Oct 2013 - Garching

Jean Paul PERIN jean-paul.perin@cea.fr
Denis CHATAIN denis.chatain@cea.fr

Cryogenics at CEA/Grenoble (1957 birth of the lab)





Fields of interest

Helium (4.5K), Helium II (1.8K) and other gases

thermohydraulic studies, supraconducting magnets cooling
hybrid magnet 33T, LHC 24 kW à 1.8K, ITER project
heat exchange and turbulence

Cryocoolers for space

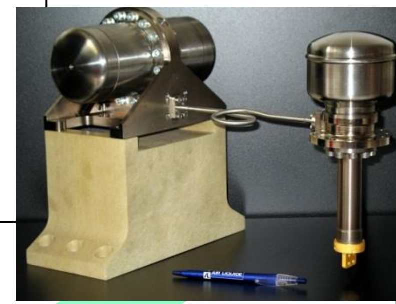
He^3 or He^4 adsorption cryocoolers (<1 K 30µW/300mK)
P.T.(single or double stage) 100W/80K , 3W/20K et 30W/40K

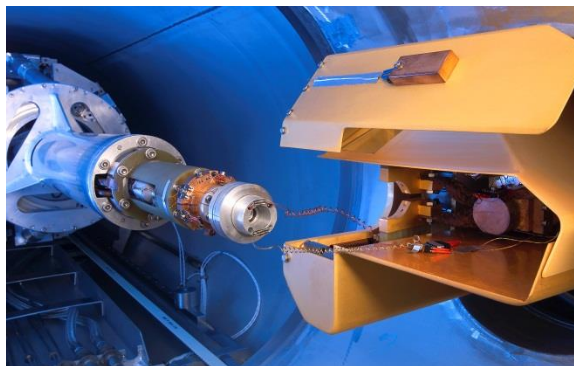
Nuclear fusion cryogenics

High speed pellet injector (D_2 4500m/s)
LMJ project (inertial fusion)

From fundamental research to applications

Realization
« customers » (ESA, CEA, ITER & BA,…), companies

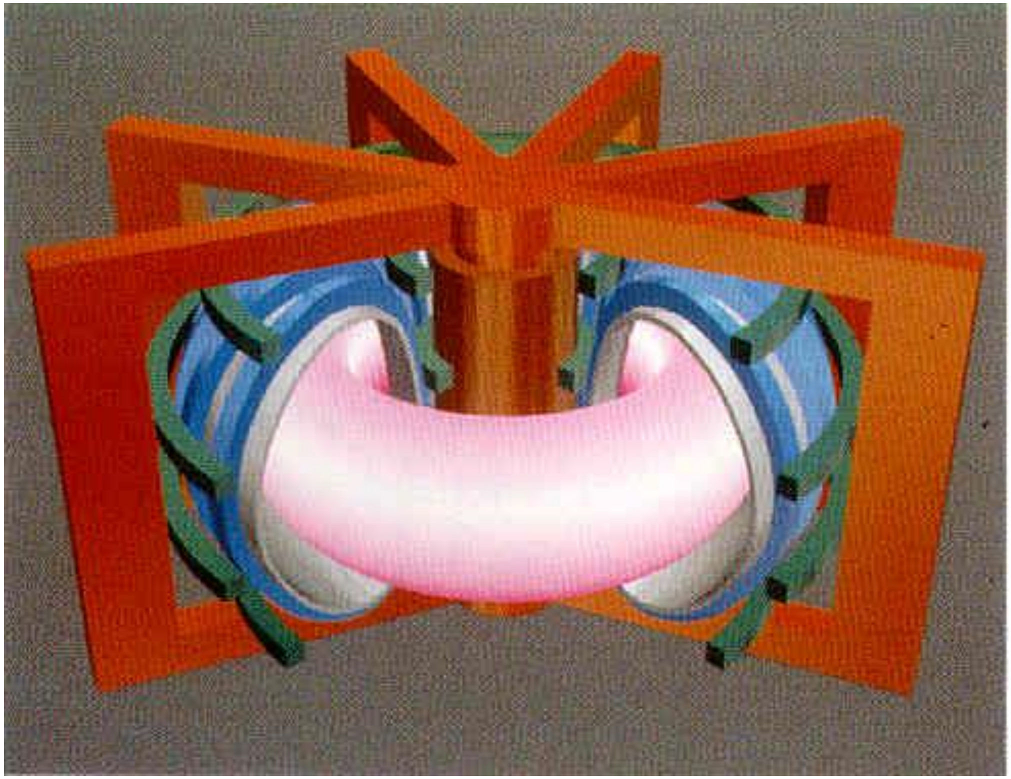




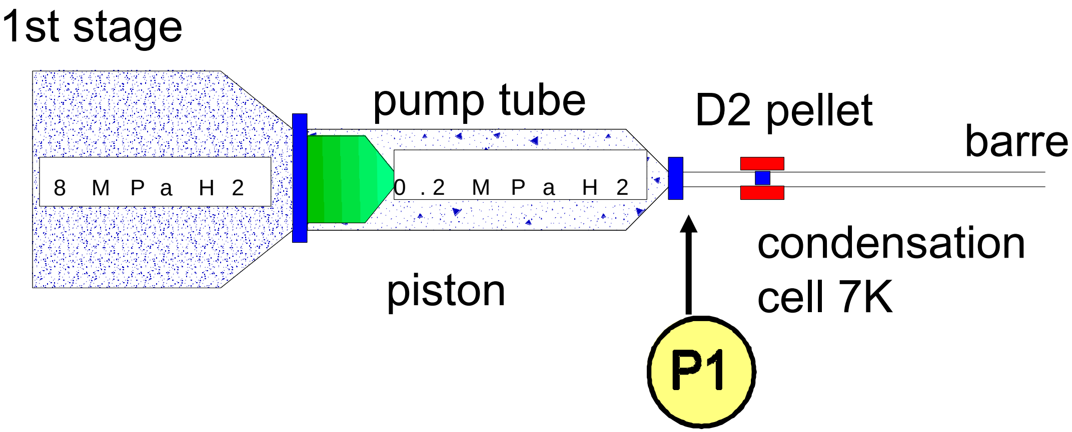
Finalized research
Prototyping, tests bed …

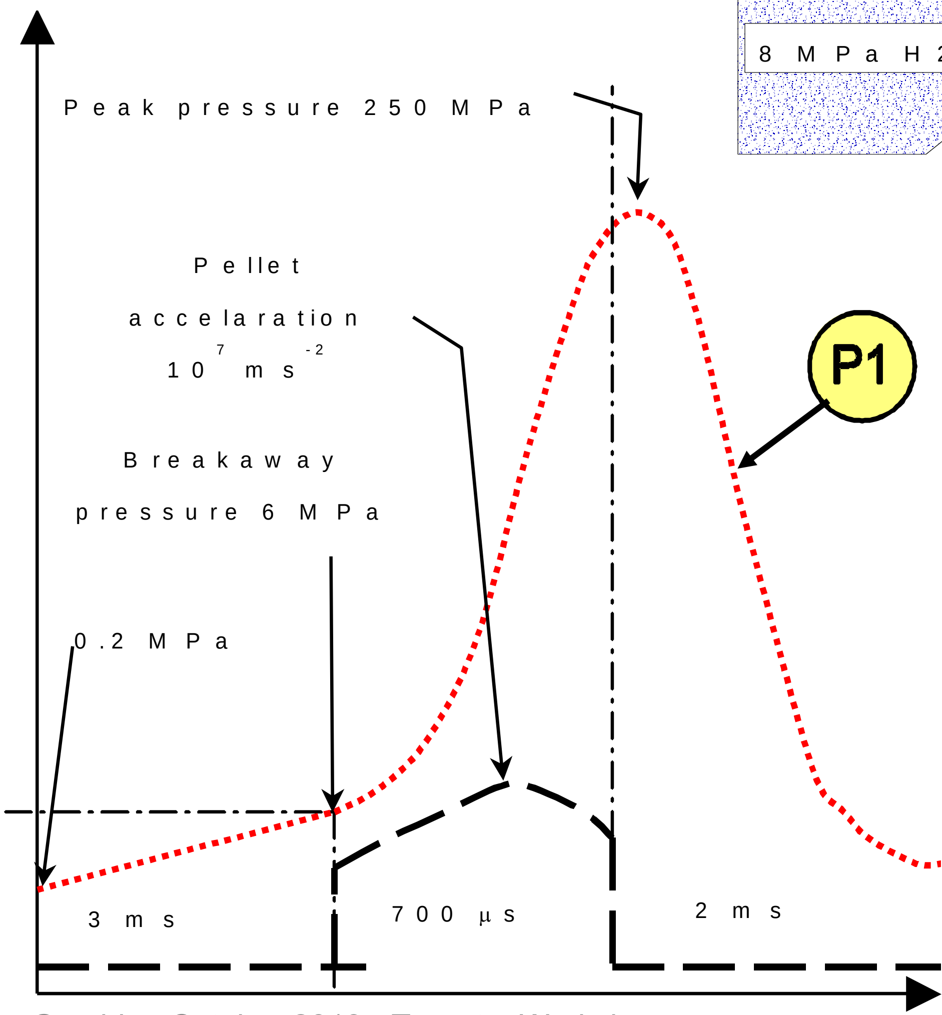
Fundamental Research
Universités, CNRS…

Croytechnology for fusion by magnetic confinment



Two stage gas gun for pellet injection 1/2





<u>Acceleration curve</u>

a(t) sound velocity

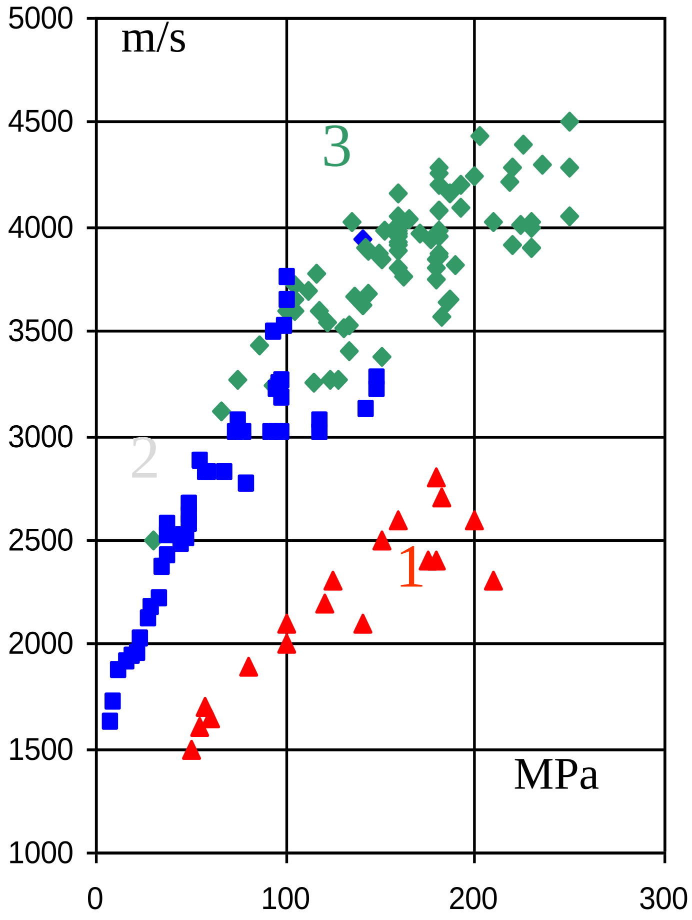
$dV/dt \approx P(t)[1-(\gamma-1)/2*V(t)/a(t)]$

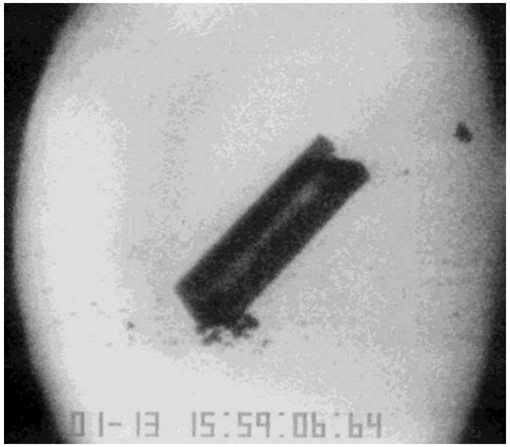
<u>Wave pressure velocity</u>

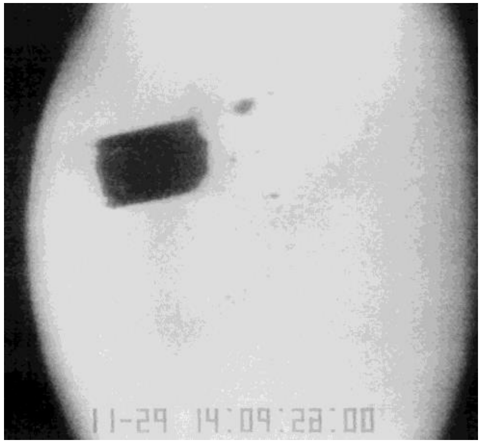
$c(t) \approx a(t)-(\gamma-1)/2*V(t)$

only the 350 µs pressure impulse after the BP are efficient

Two stage gas gun for pellet injection 2/2





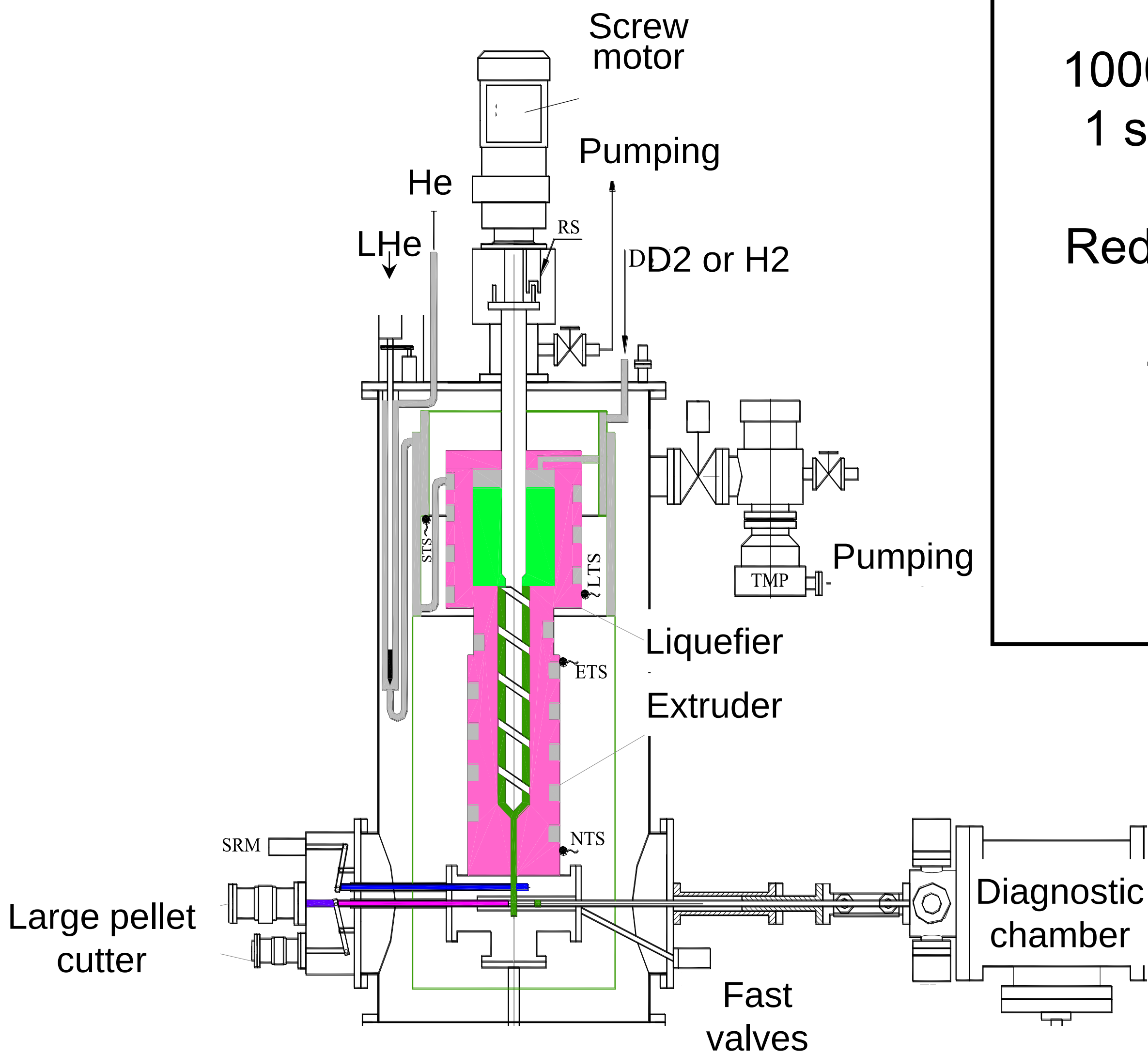


2.5 10^{21} D atoms
2560 m/s

1.35 10^{21} D atoms
3570 m/s

Pellet velocity versus breech pressure
acceleration 10^7 ms^{-2}

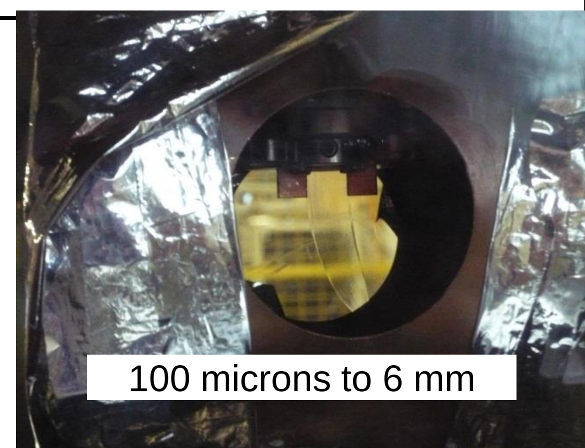
Continuous pellet injection



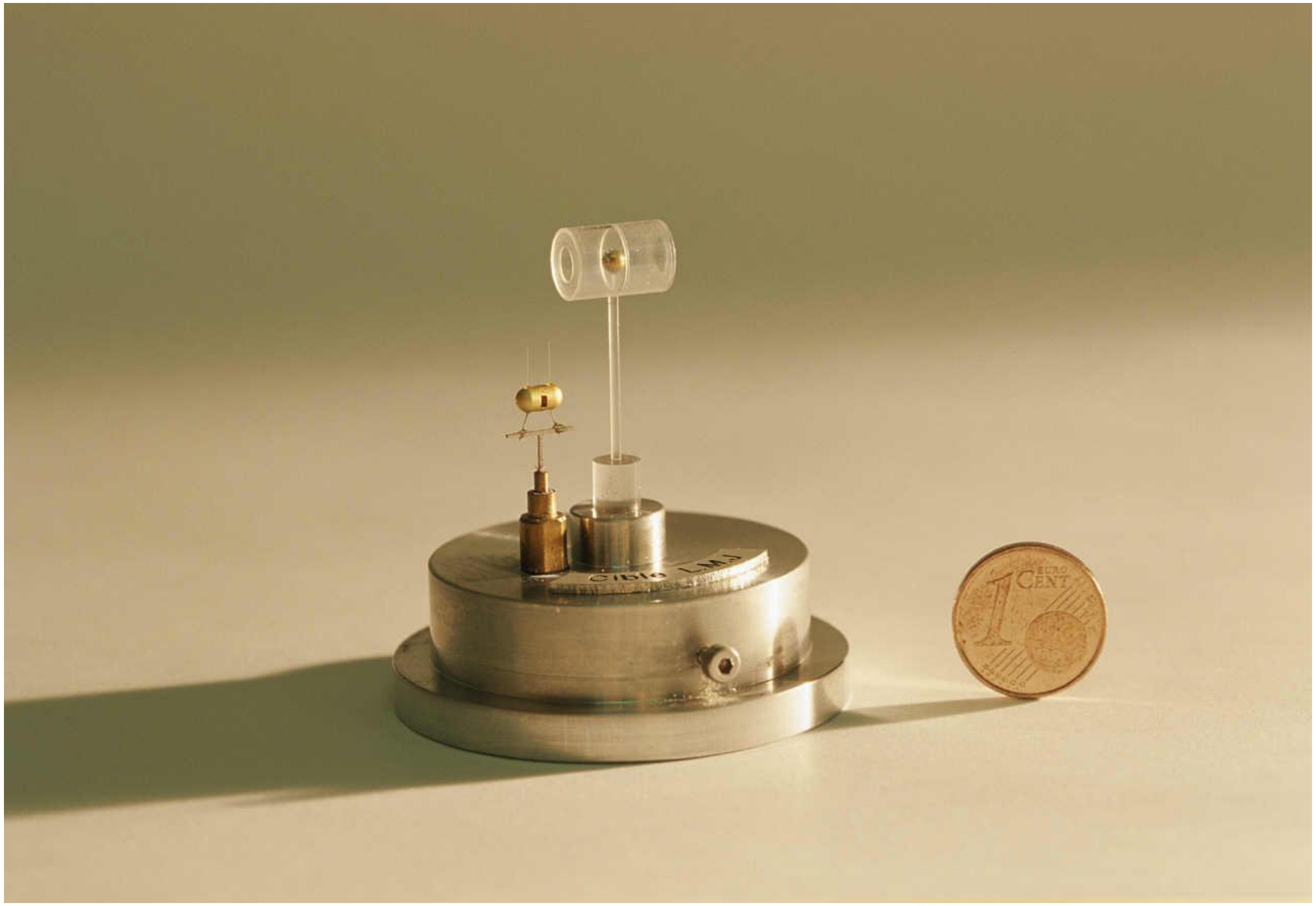
OBJECTIVES
1000 m/s @ 1000s @10 Hz
1 shot per minute to 10Hz

Reduction of propellant gas mass
< 1 time pellet mass

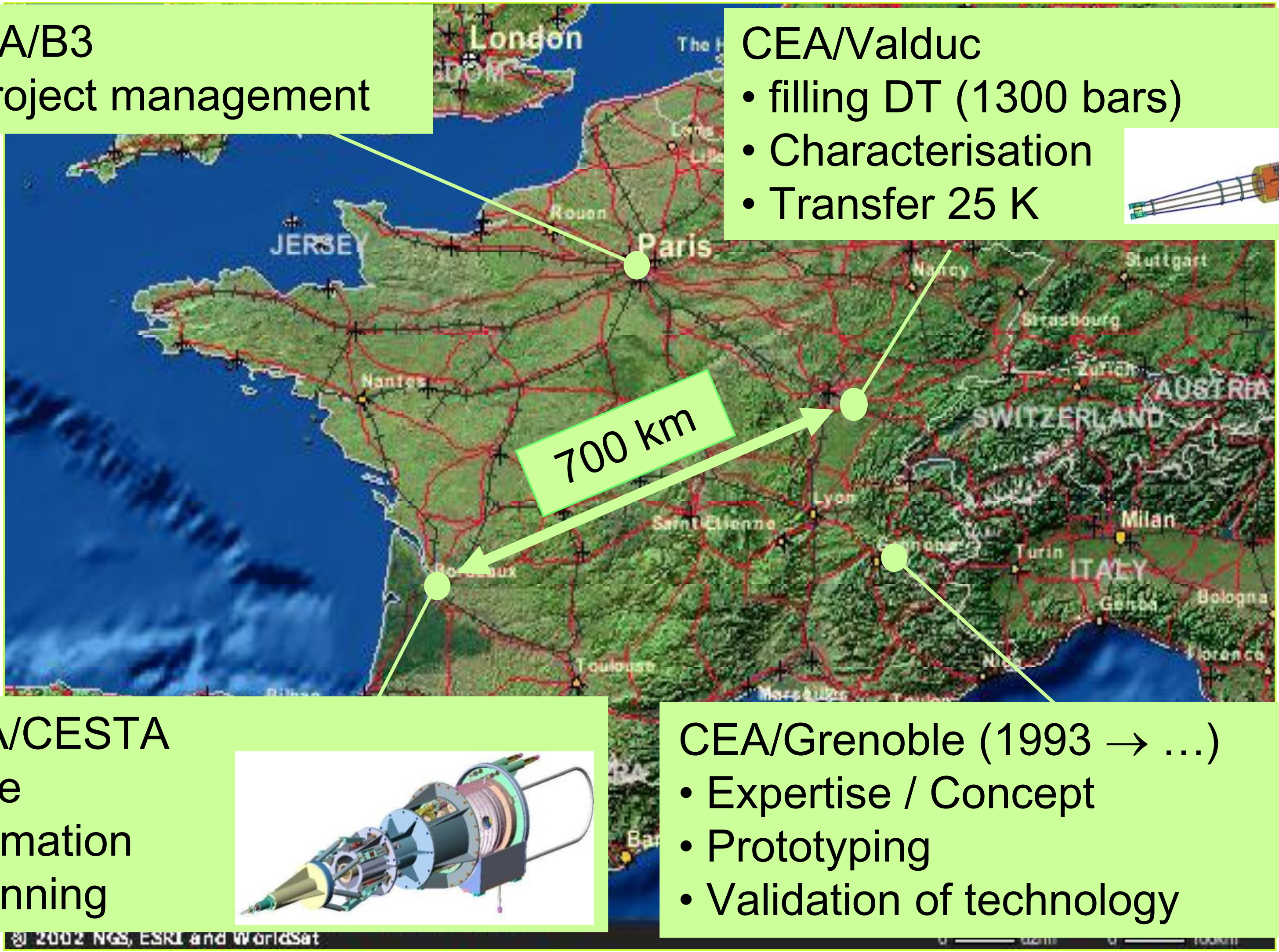
guide tube 14 m
injection HFS



Croytechnology for fusion by inertial confinment



Laser MegaJoule project (1/3)



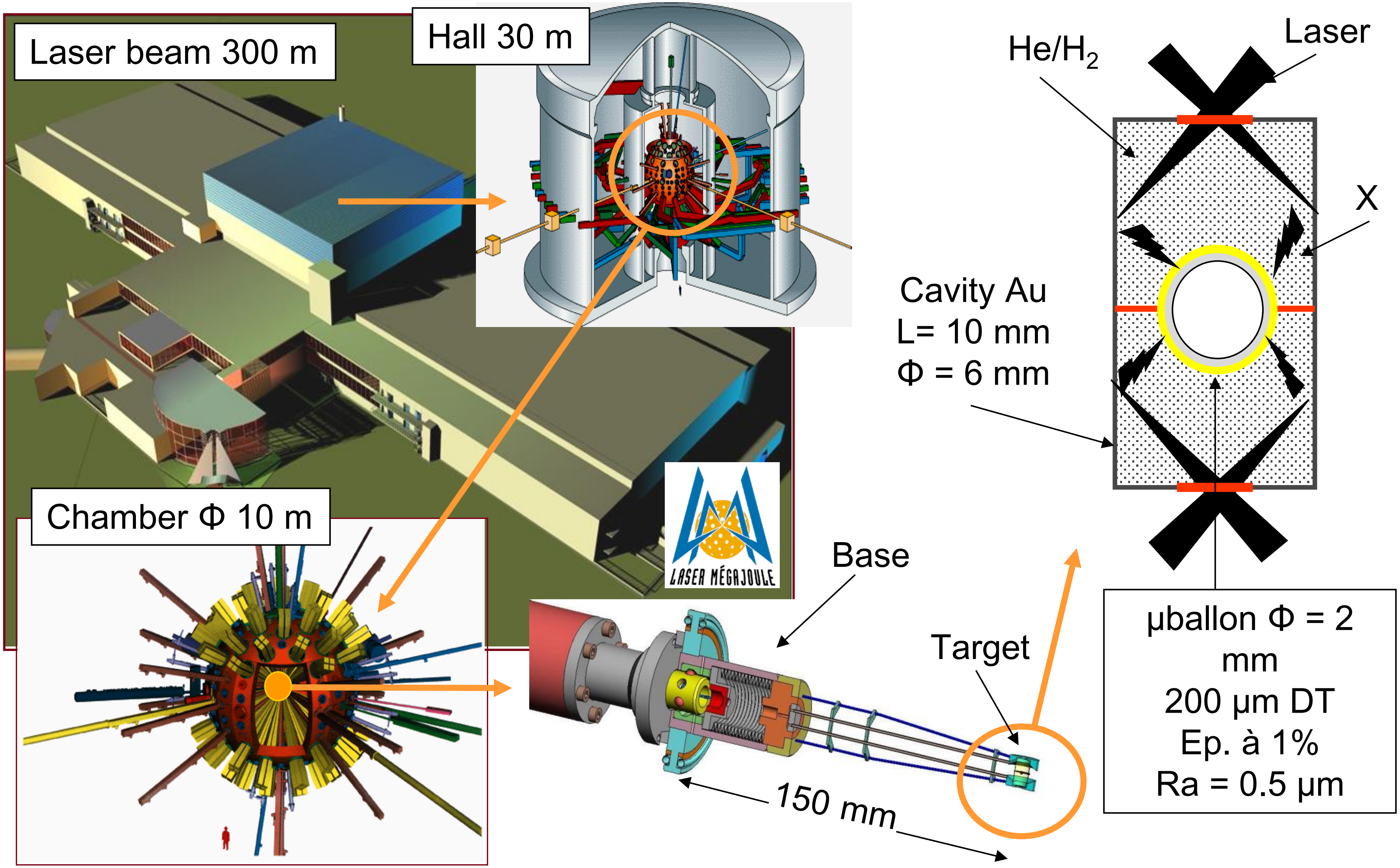
CEA/B3
- project management

CEA/Valduc
- filling DT (1300 bars)
- Characterisation
- Transfer 25 K

For CEA/CESTA
- Storage
- Conformation
- Positionning

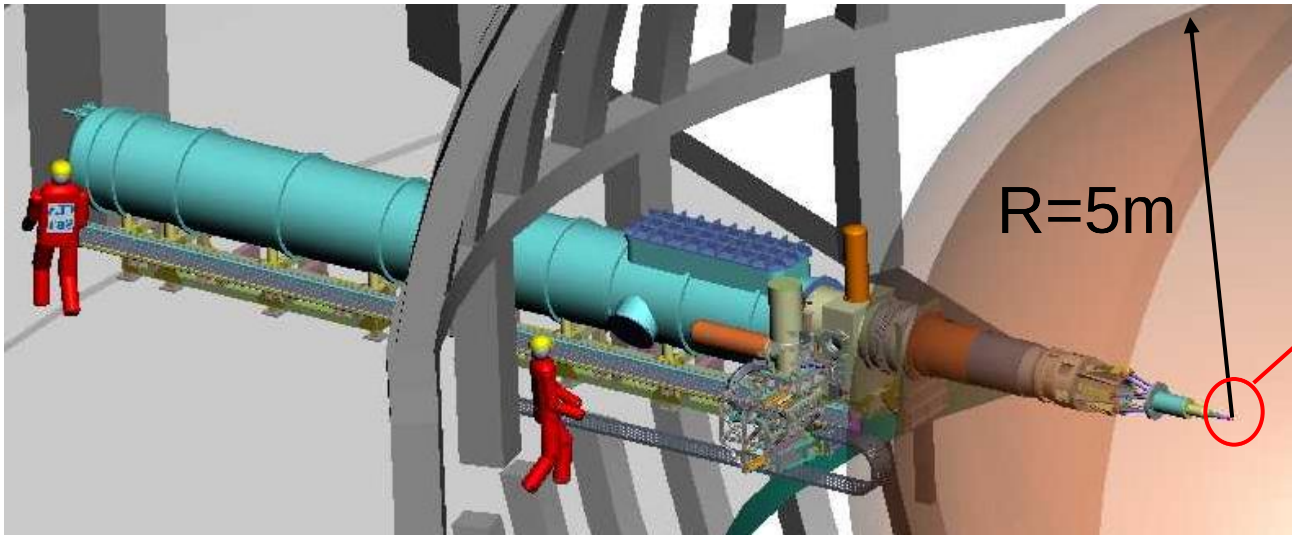
CEA/Grenoble (1993 → …)
- Expertise / Concept
- Prototyping
- Validation of technology

Laser MegaJoule project (2/3)



Laser MegaJoule project (3/3)

program > 20 years



200 µg DT
e= 200 µm +/- 1 µm
18 K +/- 1 mK
X,Y,Z +/- 25 microns

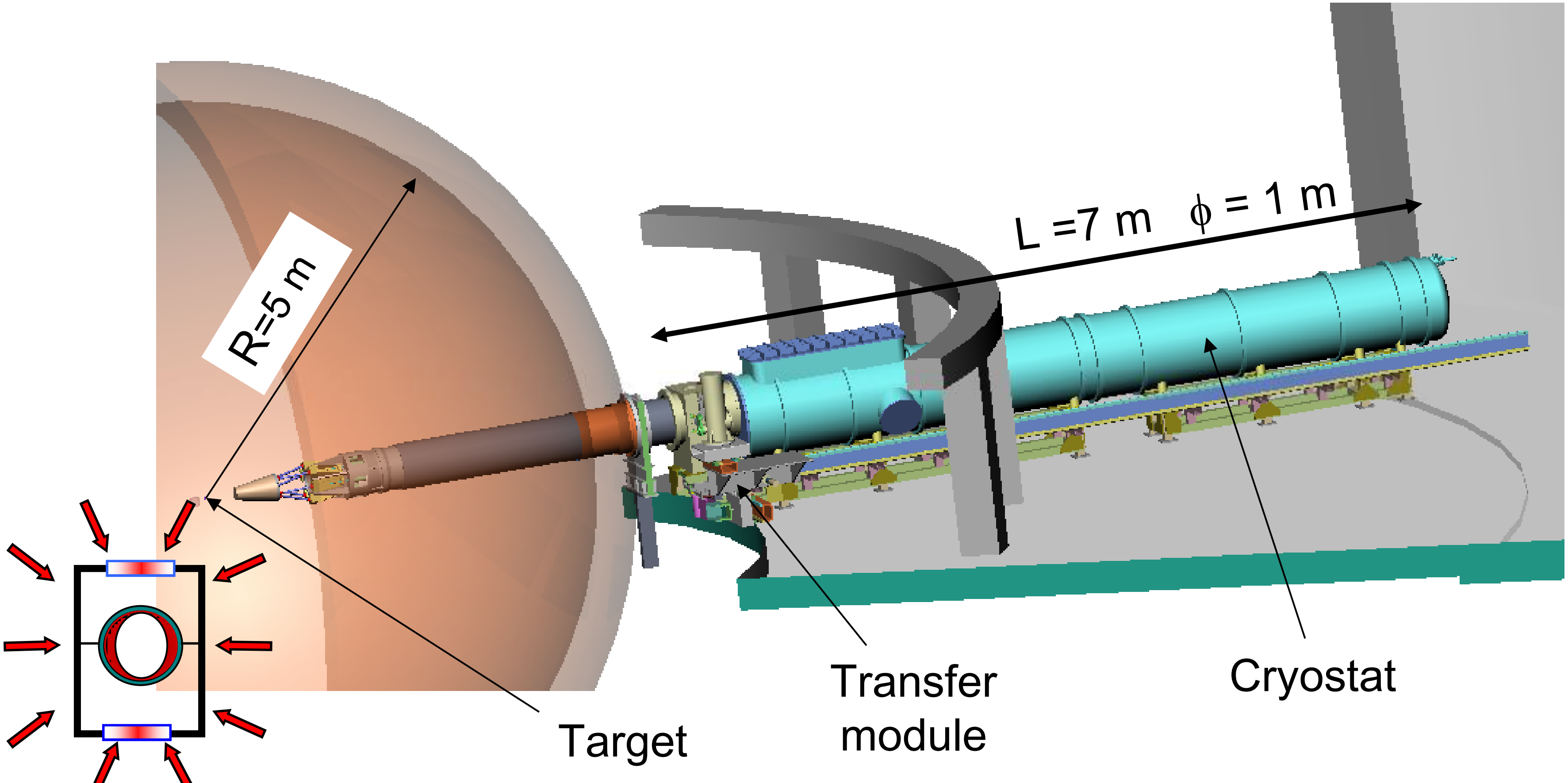
1994 1st faisability study

2000 -2009 validation of the solution « scale 1 »

2014 1er laser shot

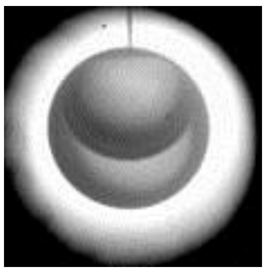
H_2 fusion fuel: LMJ project

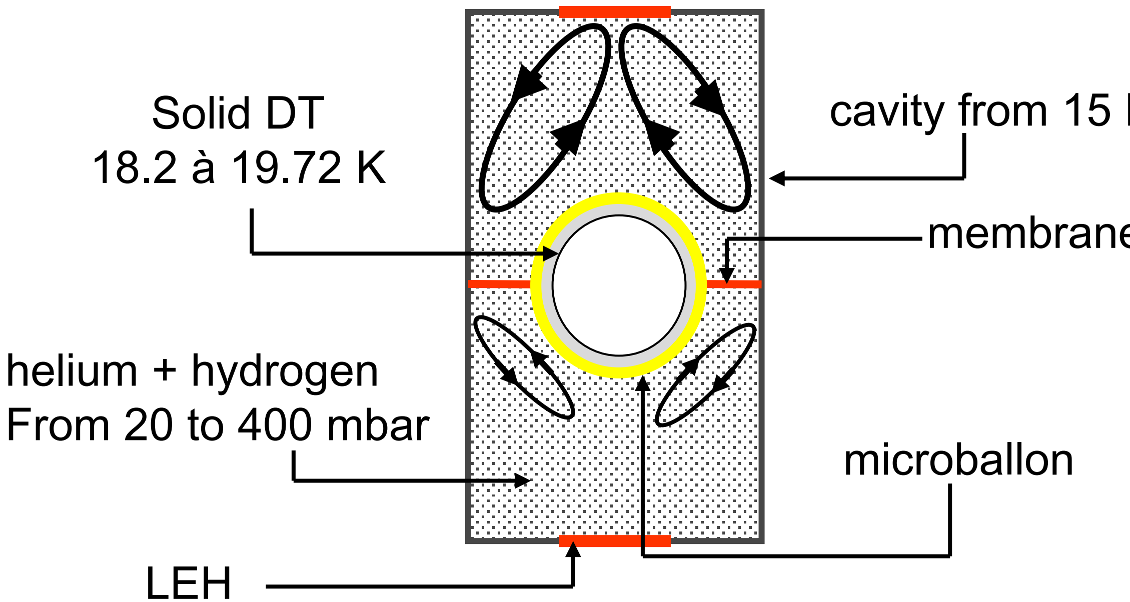
- Solidification (to PT à 1 mK/min; T_{tir} = 18.2 to 19.72 K ± 1mK)
- Positionning ± 15 µm with an hexapode
- thermal gradient < 75 µK

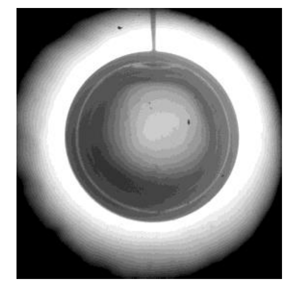


Convection

Uniform cooling







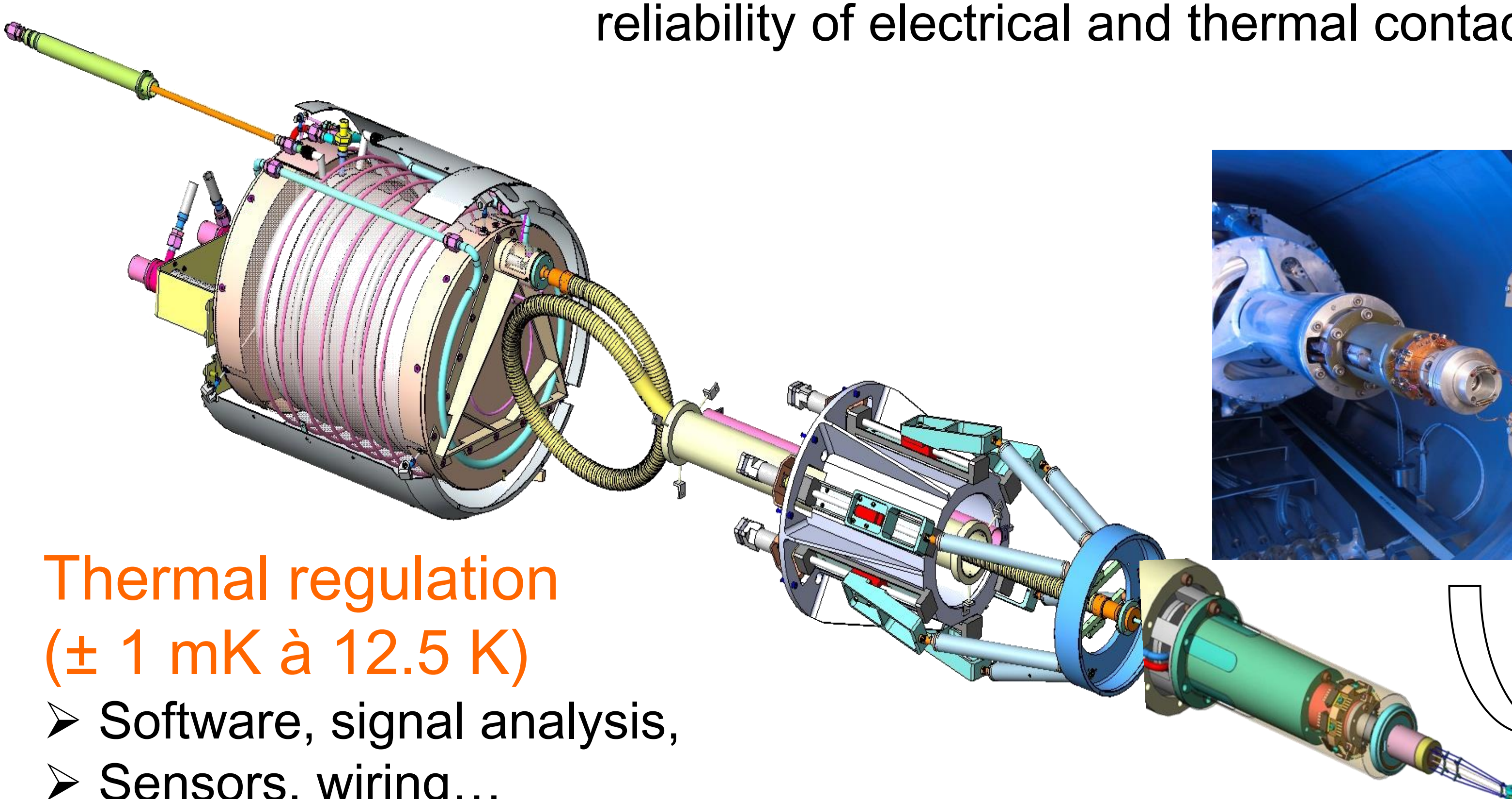
When the target is cooled down, convection movements appear. The heat exchanges are higher in the upper cell than in the lower cell.

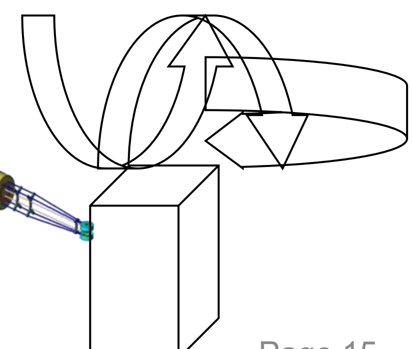
For this reason the layer thickness will be not uniform.

Solutions

Cryogenic Transfers at 20 K

- Robots working under vacuum
- Target thermal control
  reliability of electrical and thermal contacts at 20 K

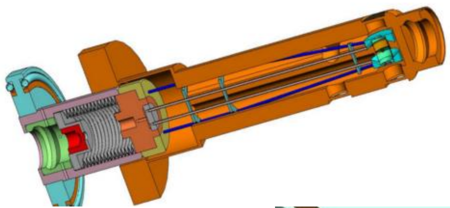


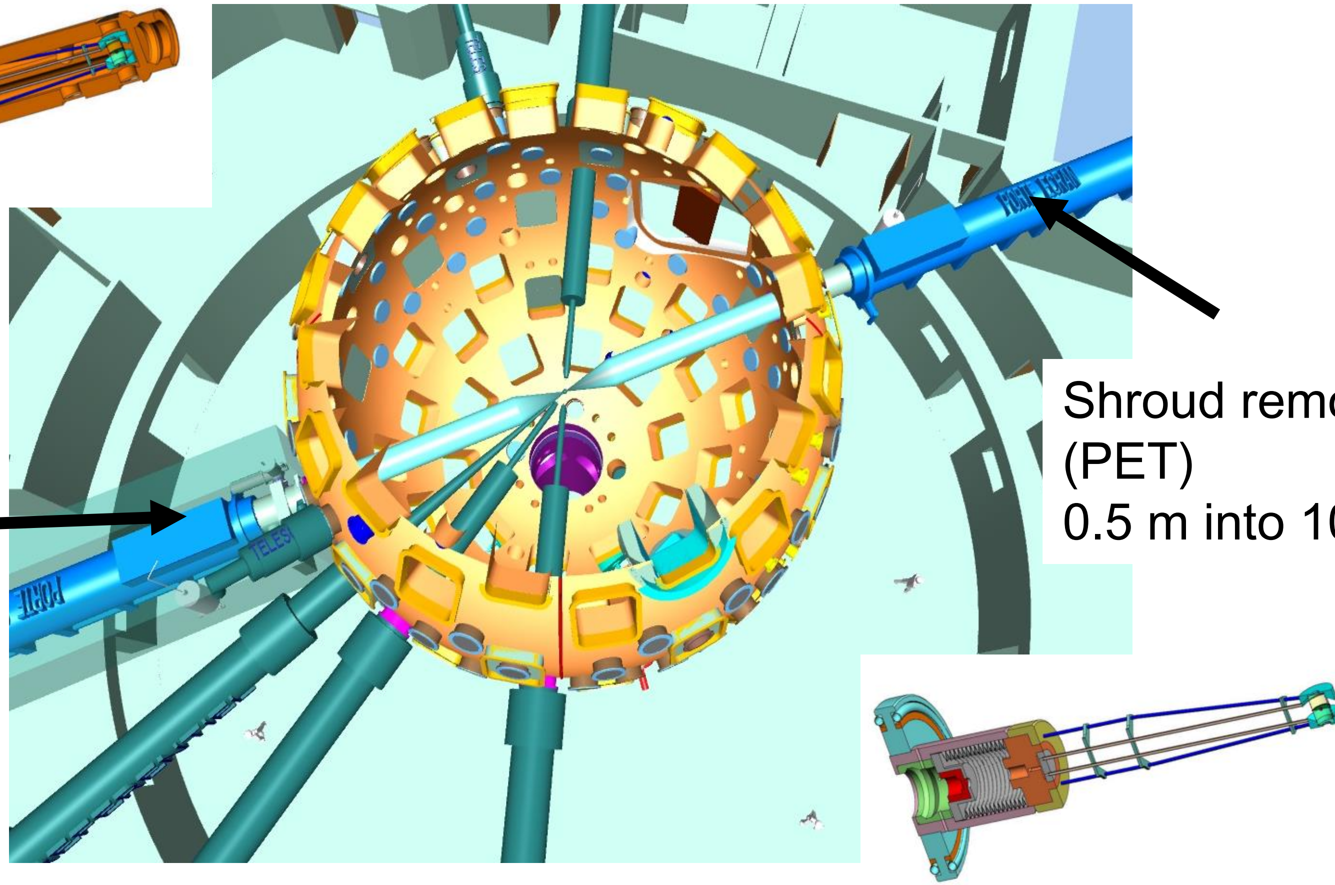


Thermal regulation (± 1 mK à 12.5 K)

- Software, signal analysis,
- Sensors, wiring…

Cryogenic equipments



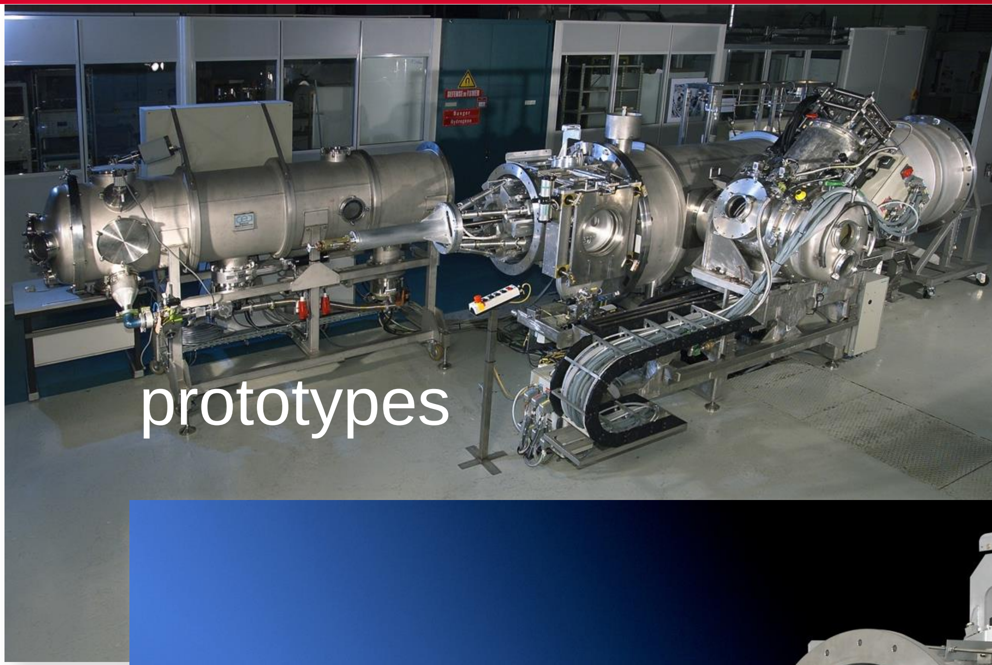


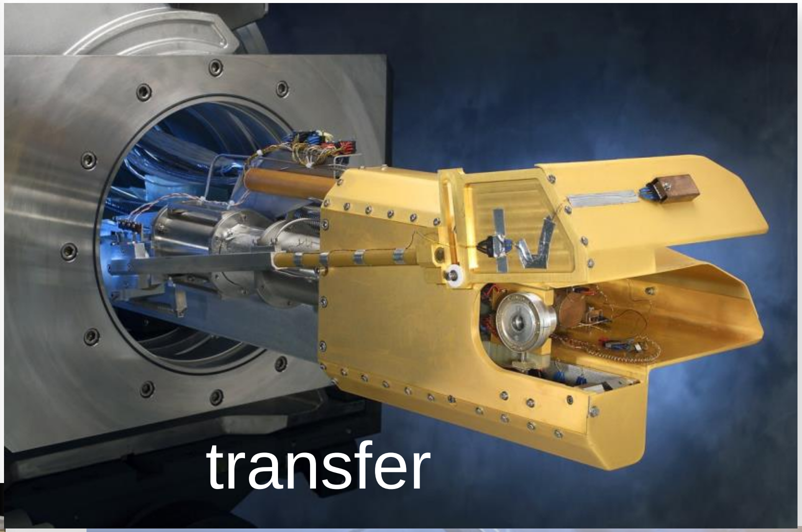
Cryotarget carrier (PCC)

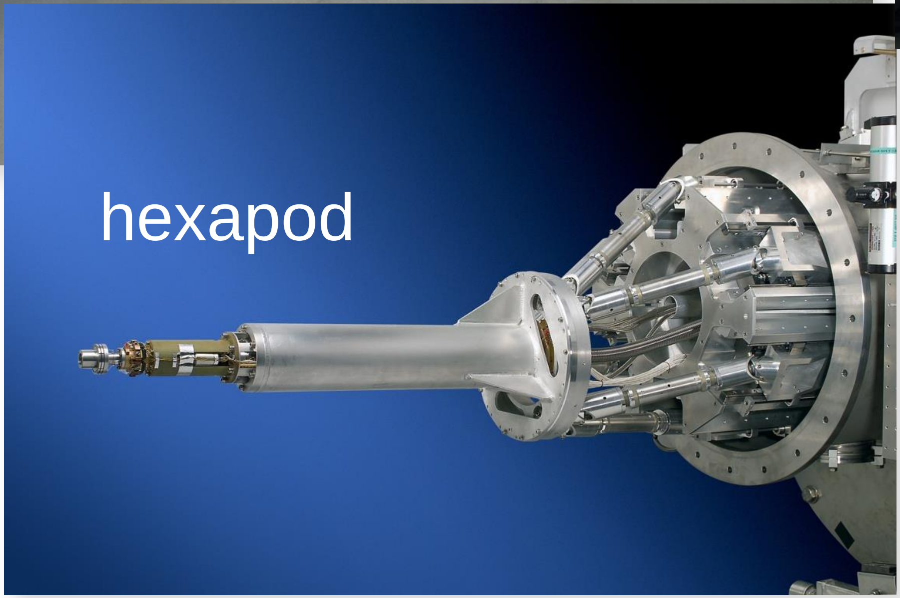
Shroud remover (PET) 0.5 m into 100ms

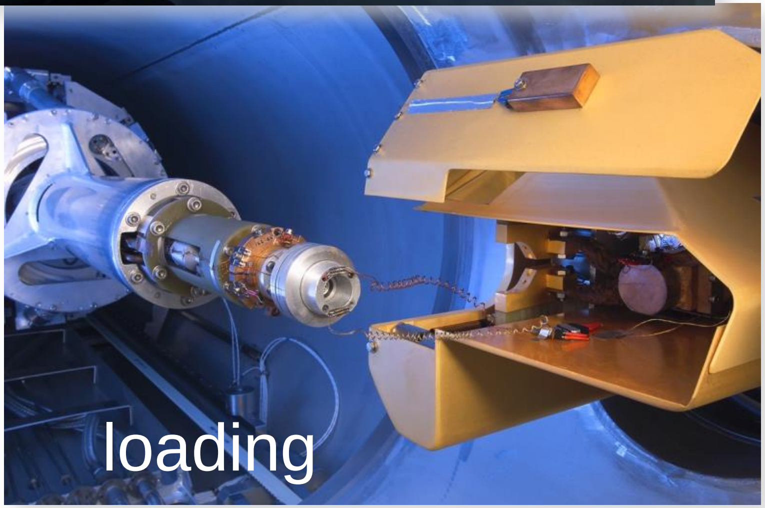
Target time life 180 ms (numerical calculations)

Some pictures…..



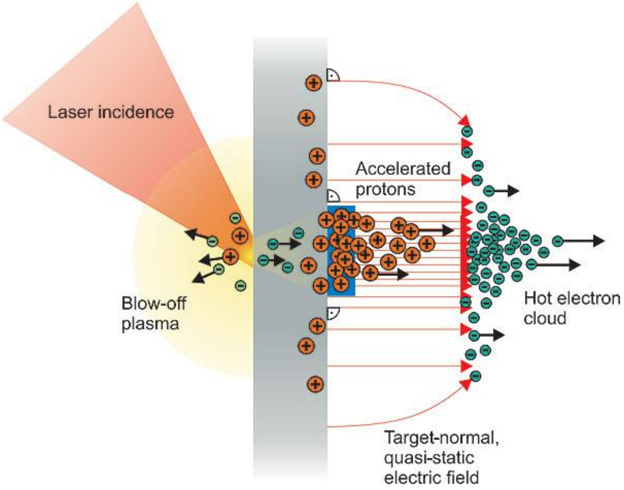






Target for acceleration particles

Goal: To produce targets of solid H_2 dedicated to laser/matter interactions



Possible application to proton-therapy

Two projects

1.- Based on H_2 solid extrusion

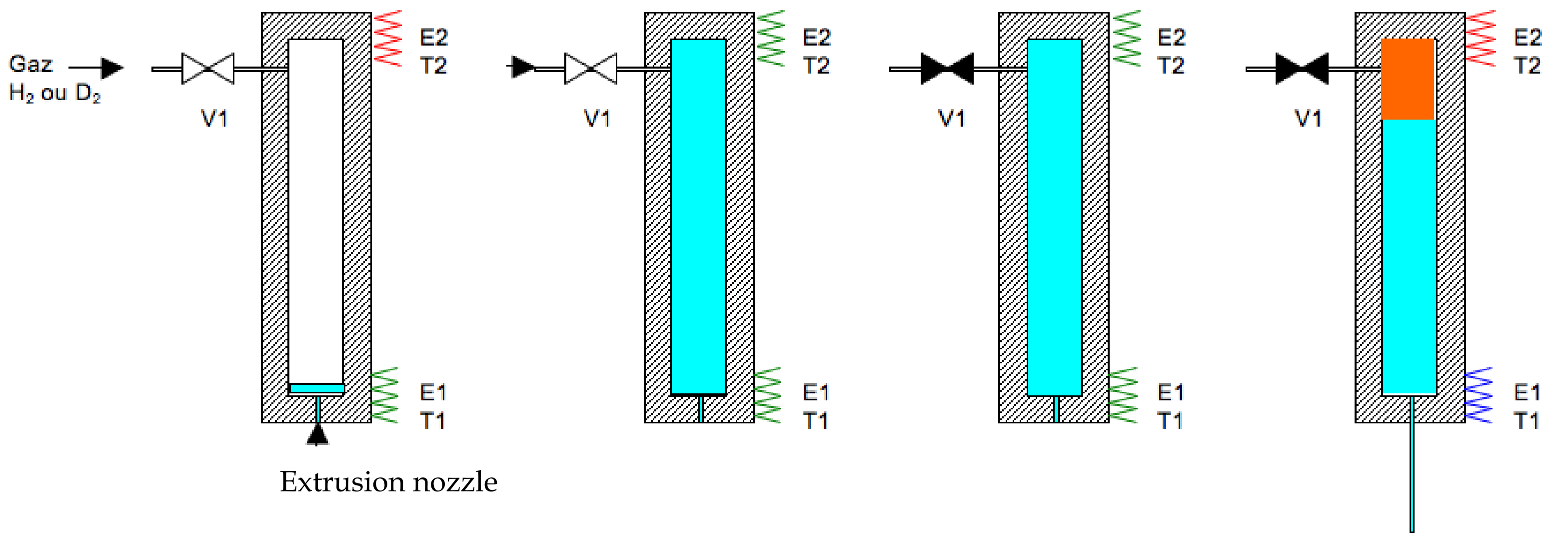
- H_2 film of 100µm to 10µm in thickness

2.- Based on H_2 condensation on a cold tape

- H_2 layer of few tens nm in thickness

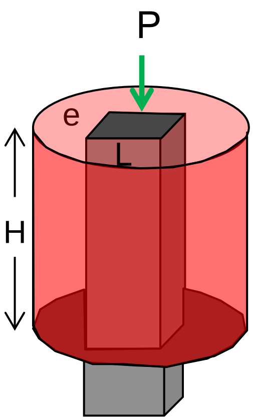
Possibility to use D_2 or Ne or other gas

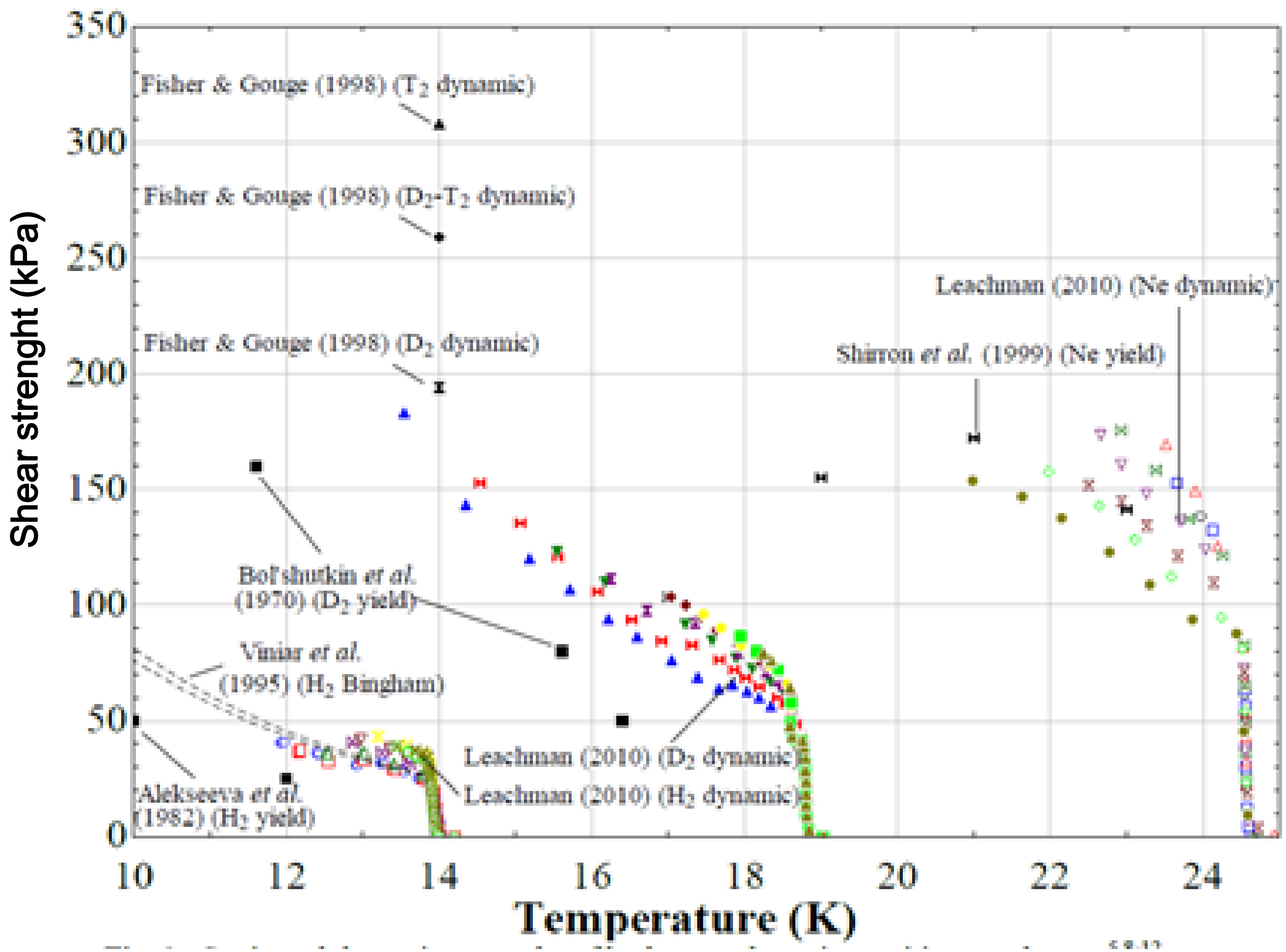
Extrusion principle (SBT patent)



- No moving part
- Utilization of the thermodynamical properties of the fluid

High pressure is required

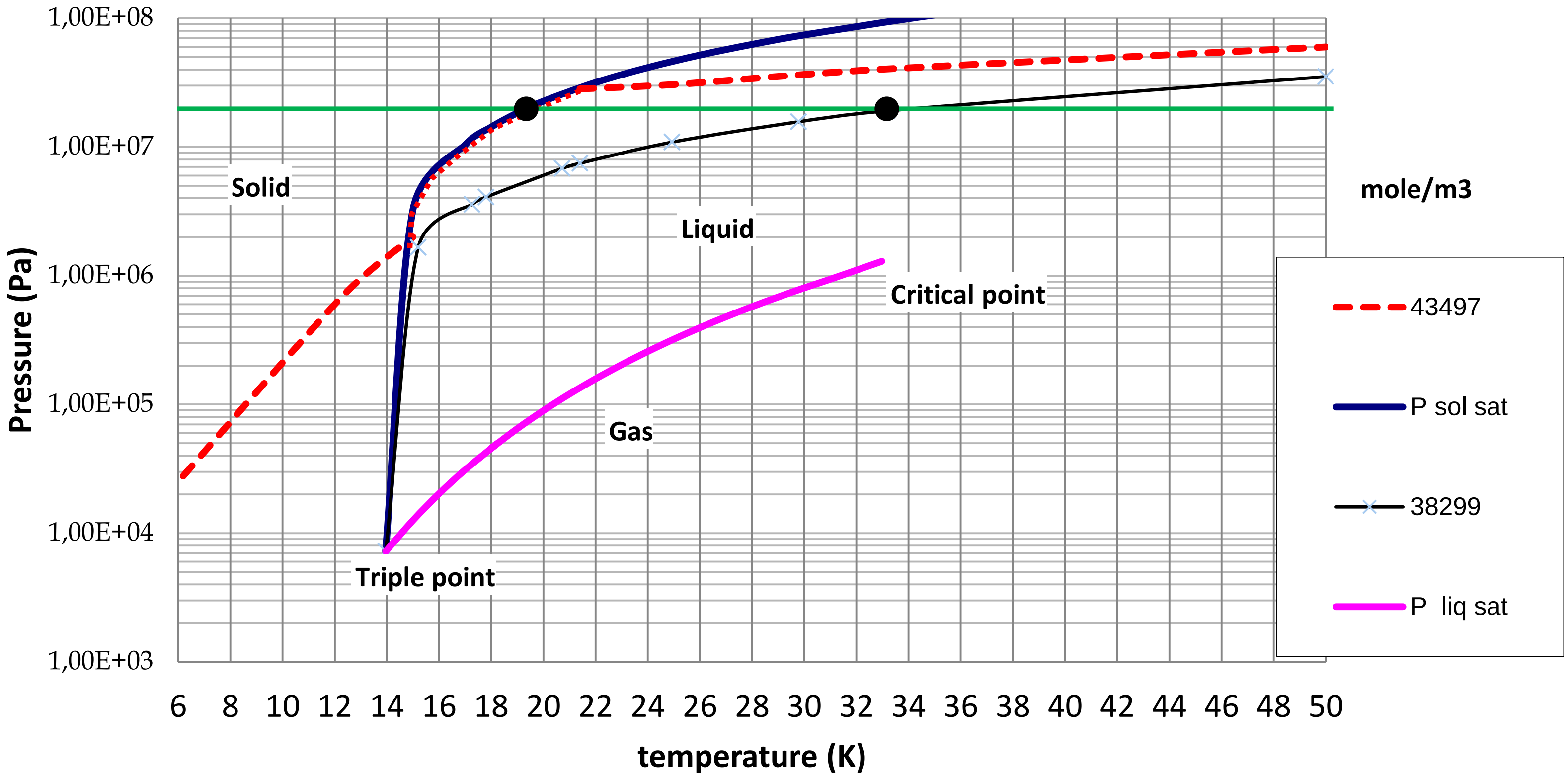




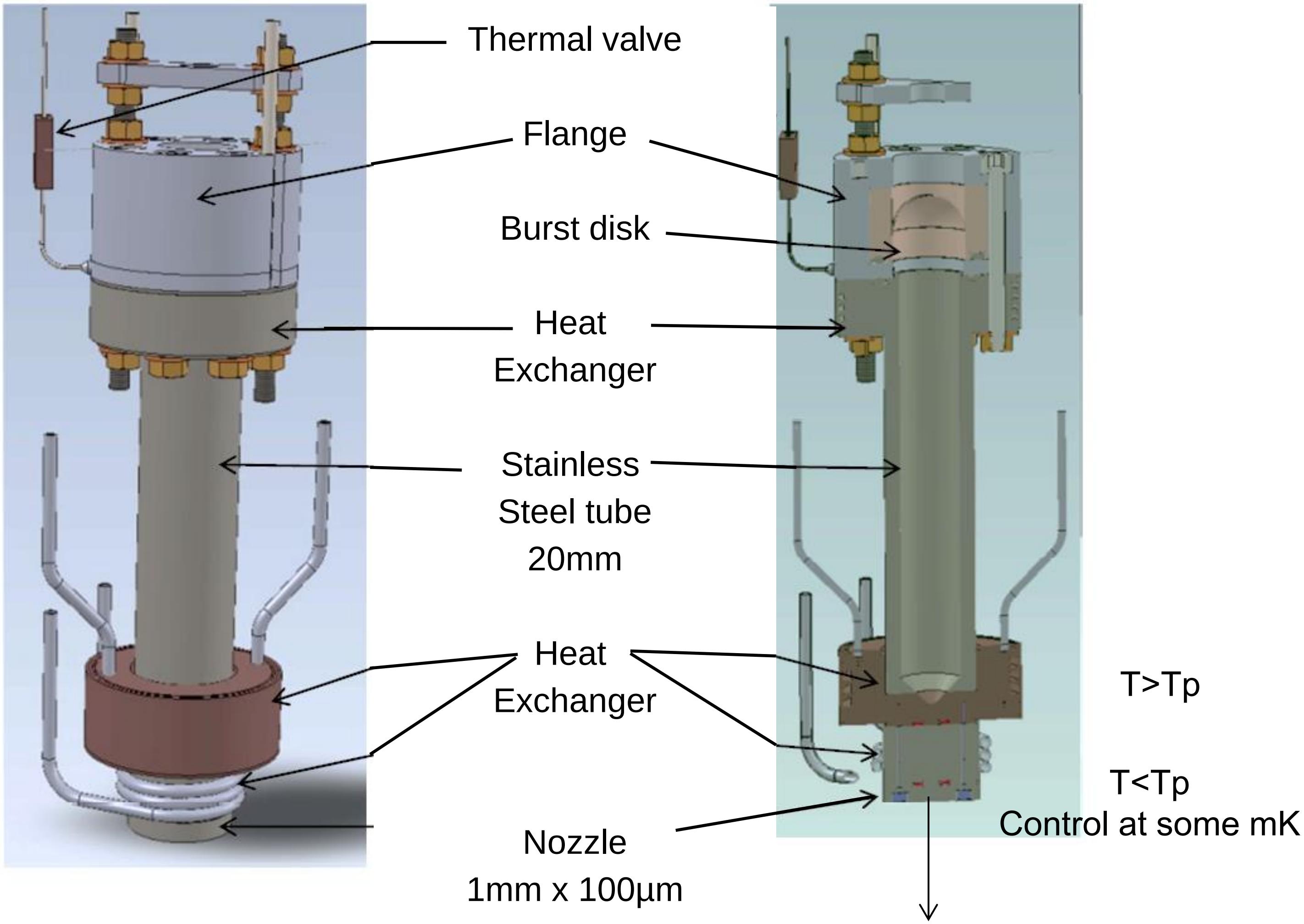
$P=2*\sigma*H/e$ (20MPa for σ=50kPa, H=2mm, L=1mm and e=10µm)

Hydrogen properties

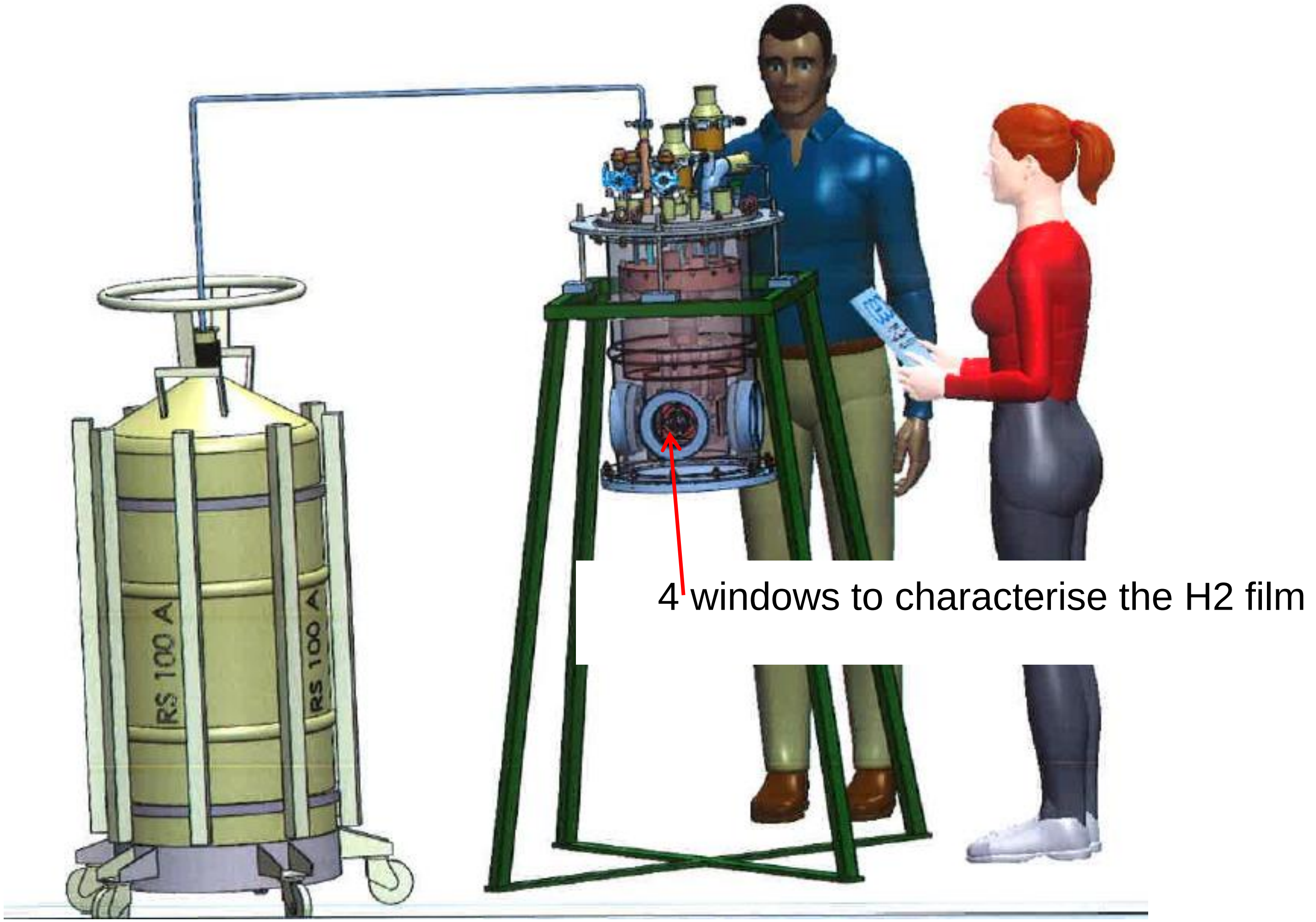
H_2 phase diagram and isodensity



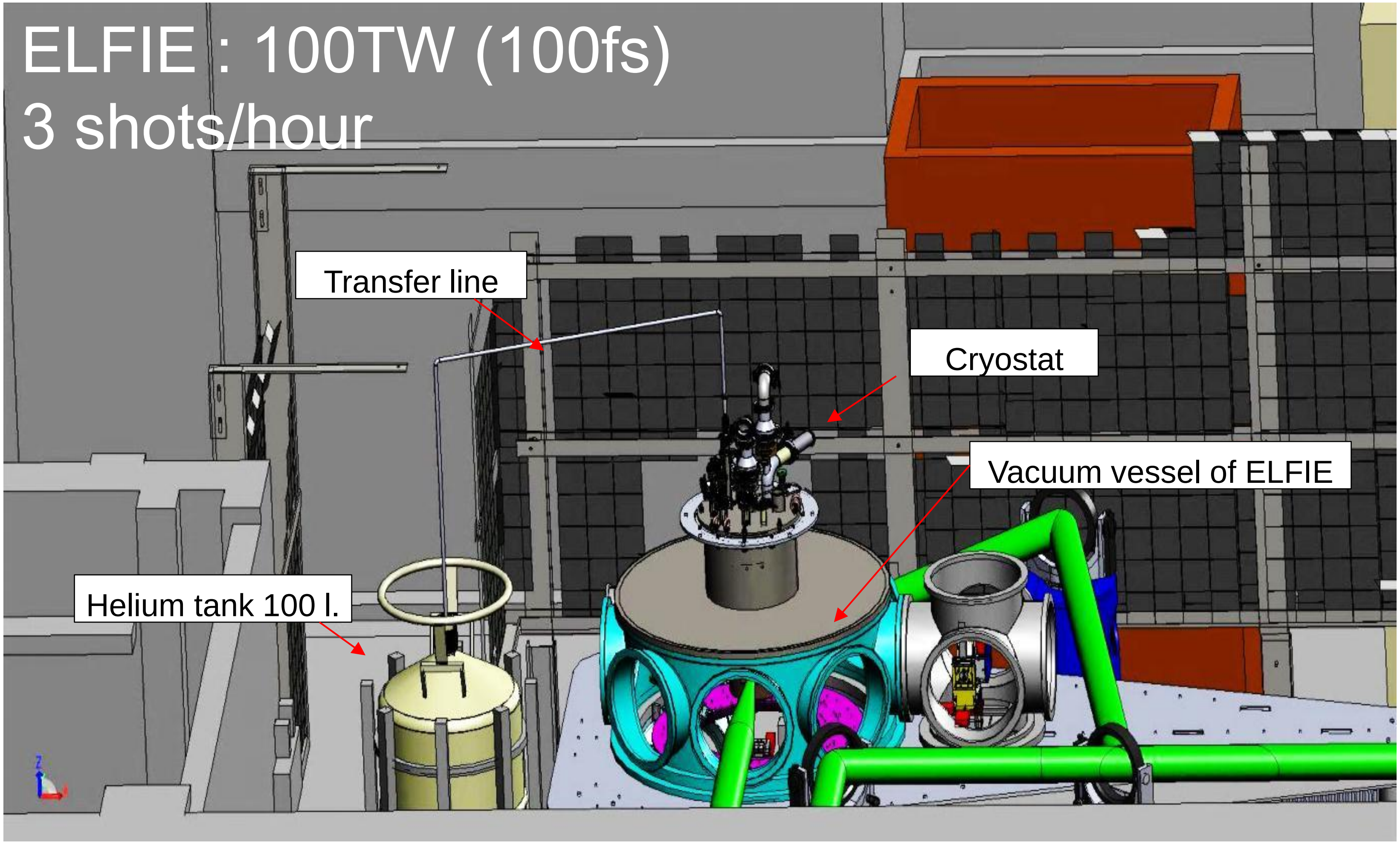
First experiments were performed in a 20mm x 100mm cell



A new cryostat is under fabrication

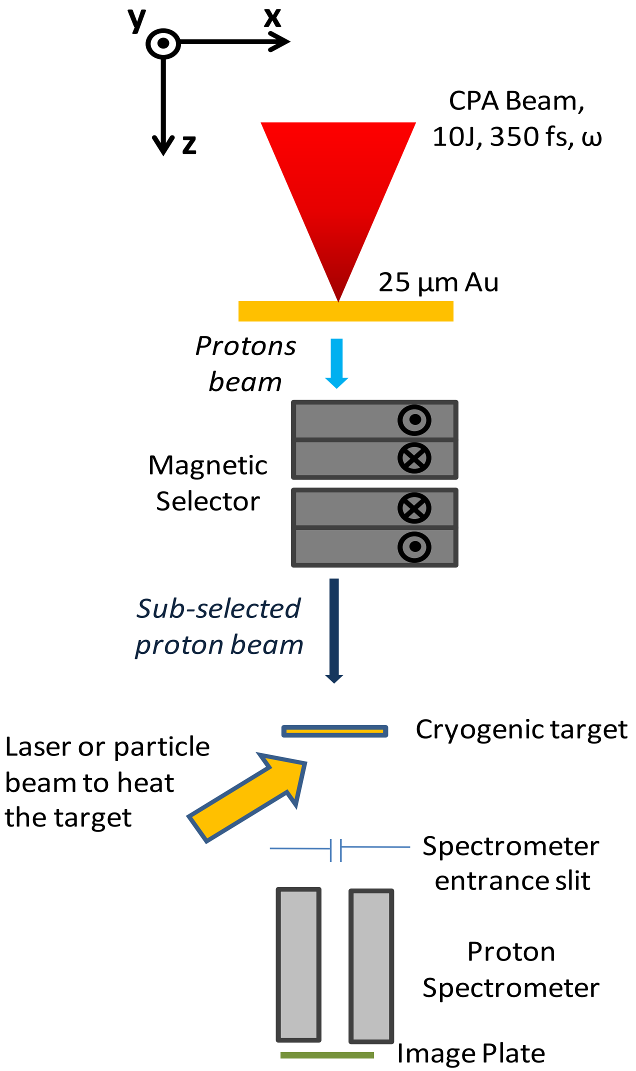


Next step: tests in 2014 on ELFIE at LULI
and after on PALS in Pragues



LISA project

Next step: tests in 2014 on ELFIE at LULI
and after on PALS in Pragues



Goal

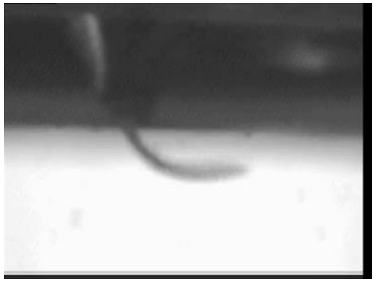
- Produce protons from several hundred kev to some MeV
- Improve the understanding of physics of ion/plasma interaction

Diagnostic means

- Two Thomson parabolas
- Xray spectroscopy

Required pumping means

$$Q(l.s^{-1}) = 22.4 * 10^5 \frac{S.V.\rho_{sol}}{M.P}$$

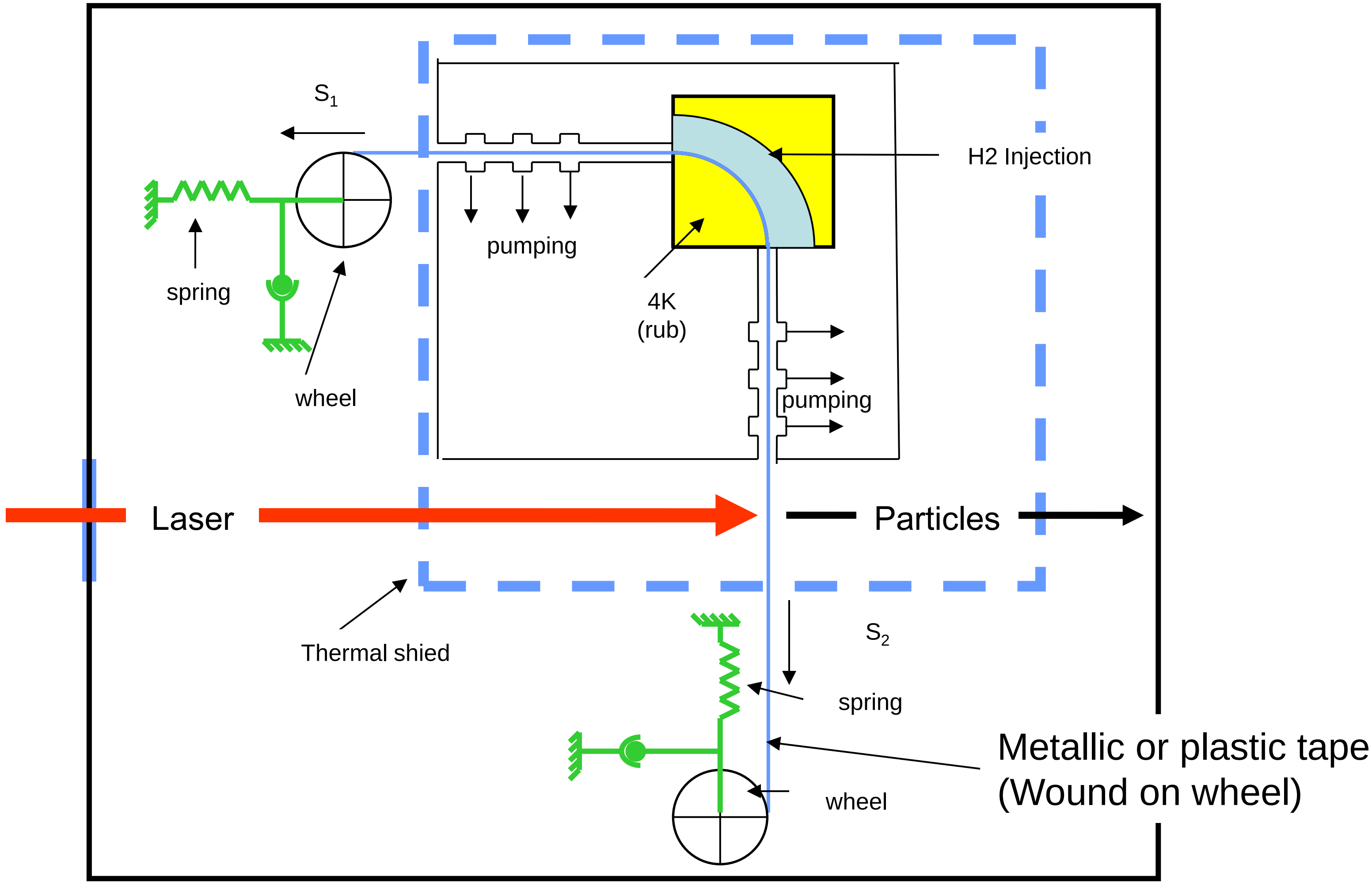


Chimène experiment
(Archimed screw system)

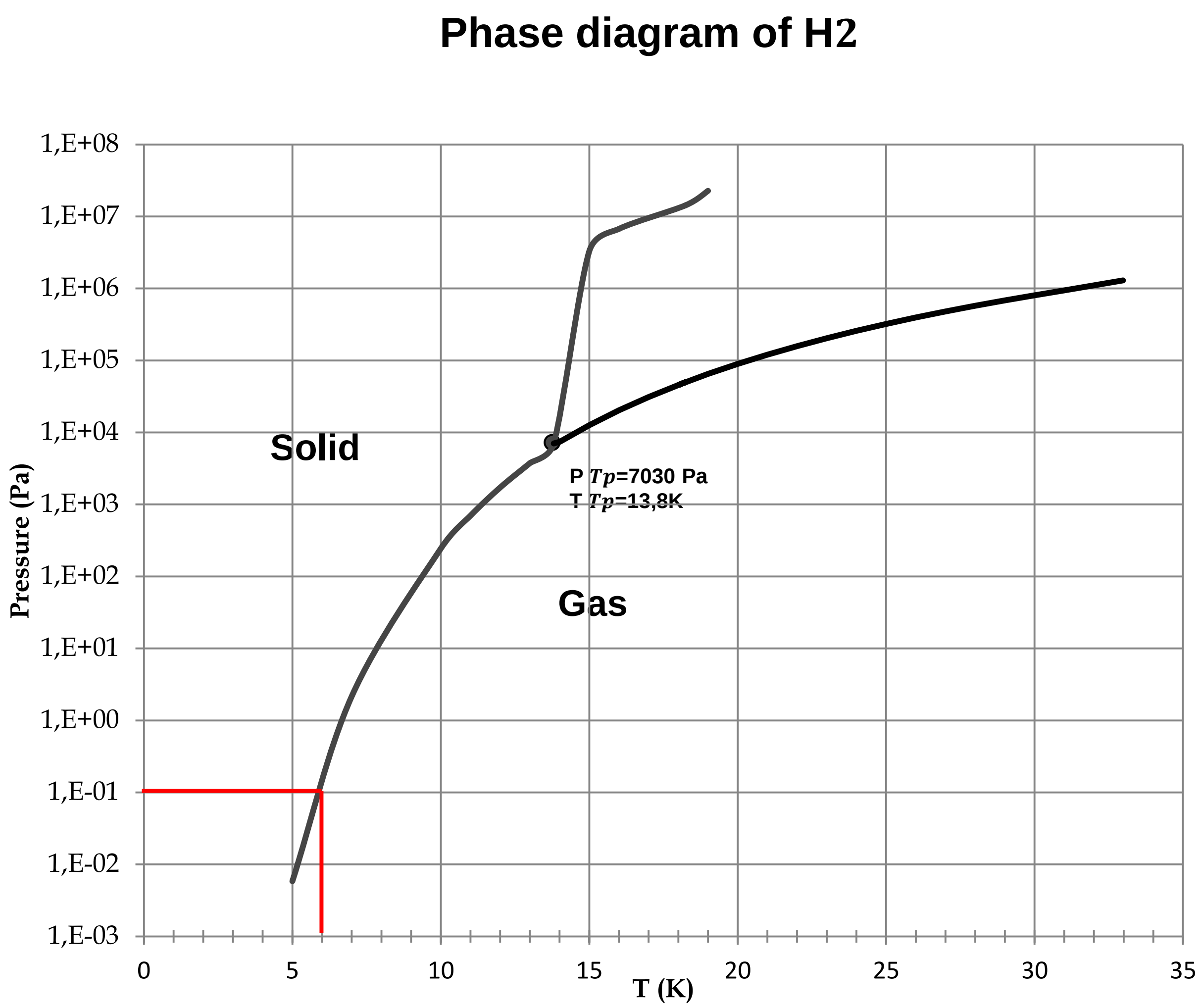
S	Foil section
V	Foil velocity
ρsol	Solid density (80 kg/m³)
M	0,002kg/mole
P	Pressure in Pa

Example: for a foil of 1mm x 100µm having a velocity of10mm/s, if the pressure in vessel is 10^{-1} Pa, a pump of 800l/s is required (compatible with ELFIE facility) → H2 management (exhaust outside)

« Tape condensation » (SBT patent)



Tape temperature

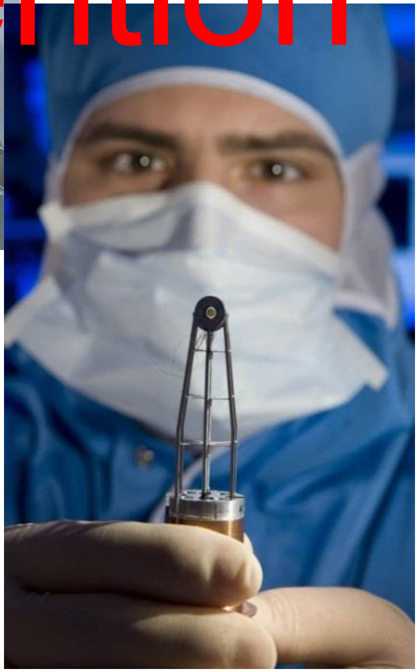


Conclusions

- Low Temperatures Laboratory can work as a partner or as an expert or as a sub-contractor for the scientific community.

- It can solve critical problems which can not be sent to industry.

- It can propose new and innovating solutions with the respect of cost and delay.



Thanks for your attention