POLITÉCNICA

ASSESSMENT OF THE BEHAVIOUR OF HIDROGEN ISOTOPES AND HELIUM IN A W ARMOR FOR INERTIAL CONFINEMENT

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HiPER

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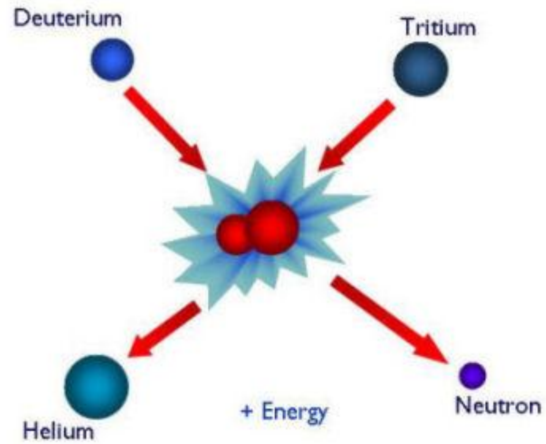
Brief introduction to Nuclear Fusion

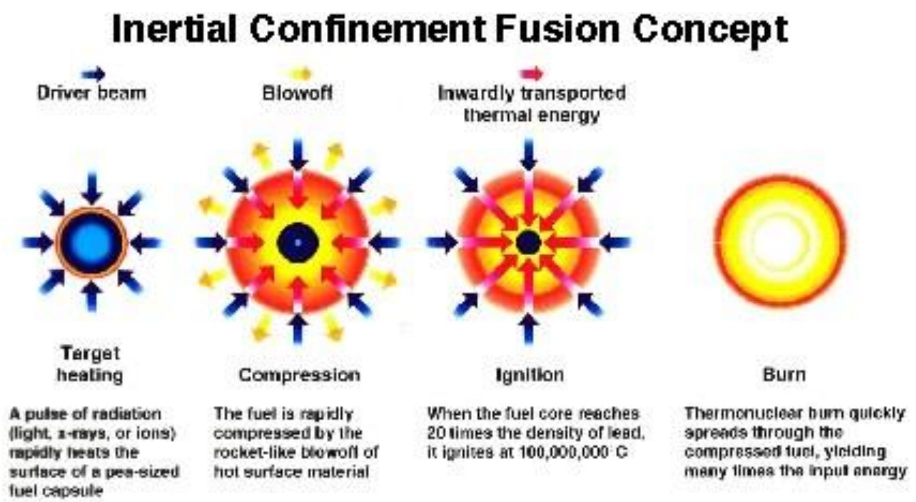
Fusion Reaction:



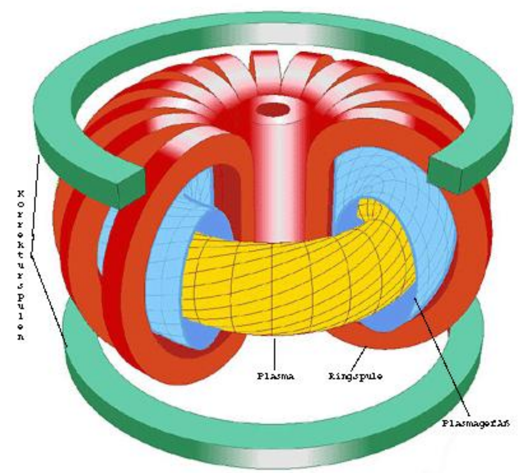
Formulation D + T → He

¡¡Extremal conditions!!

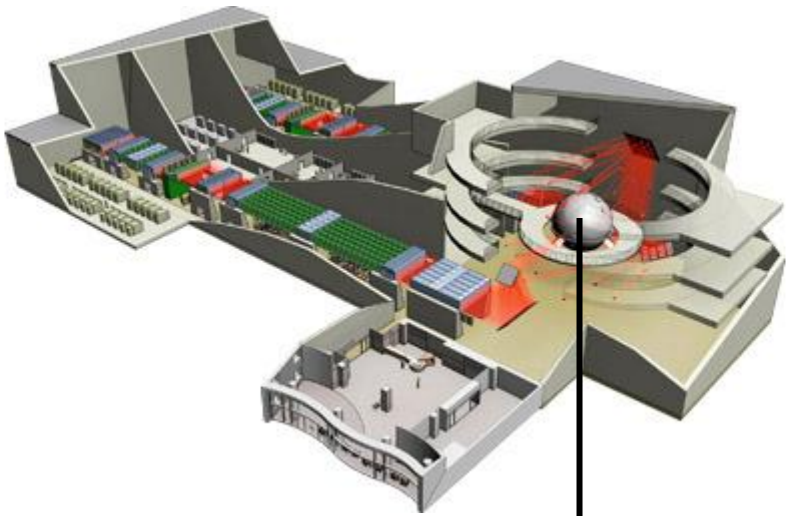
Inertial confinement: Laser drive



Magnetic confinement: Tokamak
ITER project

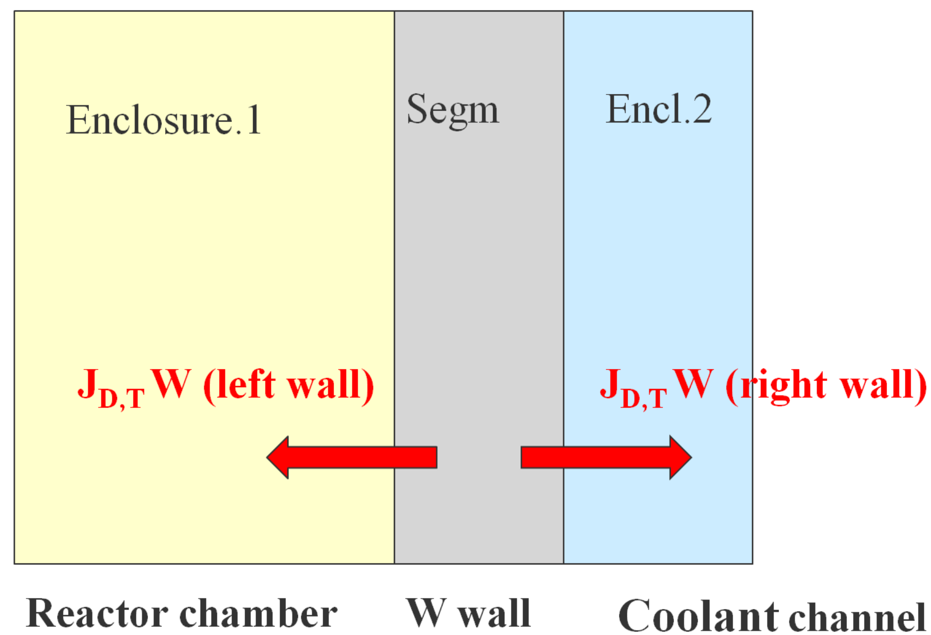


HiPER

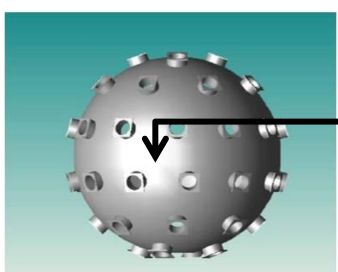


European **Hi**gh **P**ower laser **E**nergy **R**esearch facility dedicated to demonstrating the feasibility of laser driven fusion

Block diagram showing HiPER Phase 4a representation on TMAP7:



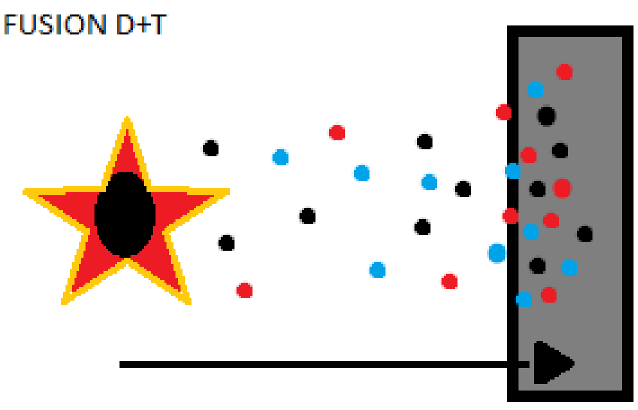
HiPER Phase 4a reaction chamber. 5 meters inner radius.



HiPER4a

CONDITIONS FOR HiPER4a

- 100 shoots at 10 Hz with just 5 fusion explosions.
- Light species yield of a 48 MJ shock ignition target which are transported and implanted in a 1 mm thick W wall.
- Atoms energy: up some MeV
- W temperature 2000ºC after each shot. It will decrease in microsec. to coolant temperature.
- Coolant temperature 600ºC.
- Reactor chamber is under high vacuum conditions. (10^{-3} mbar)

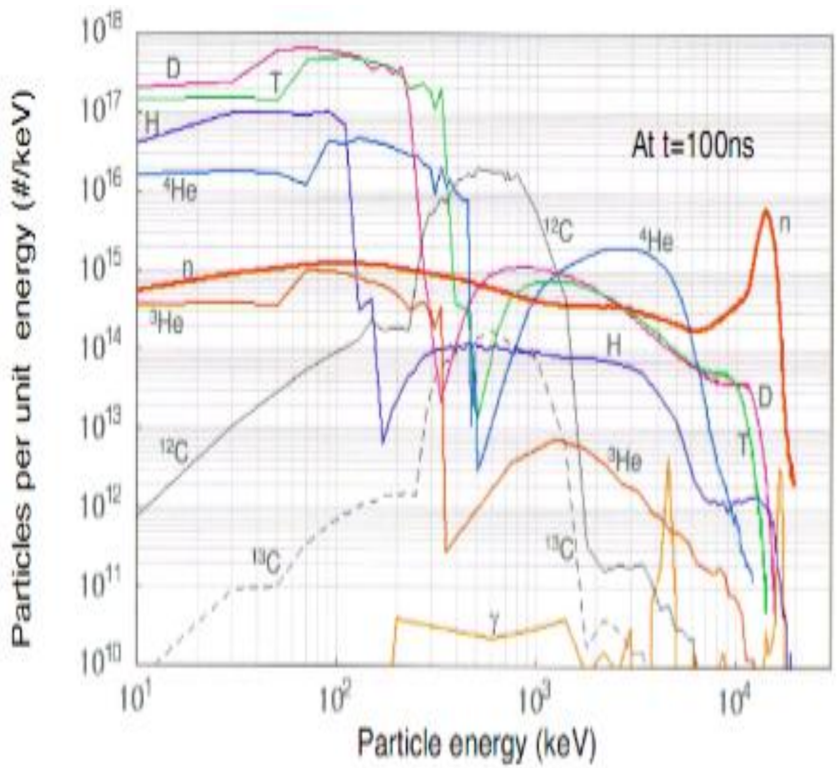


MAIN PRODUCTS: D,T,He

HiPER4a

Fusion Products

Particle	Energy (kJ)	%	N. Particles	%
H	270	2,19%	1,18e19	4,87%
2H	3200	25,90%	1,05e20	43,32%
3H	3550	28,74%	9,45e19	38,98%
4He	3630	29,38%	1,7e19	7,01%
12C	1680	13,60%	1,38e19	5,69%



For 48MJ→η=15%

D_0 =1,2E^{20}→D_1= 1,05E^{20}

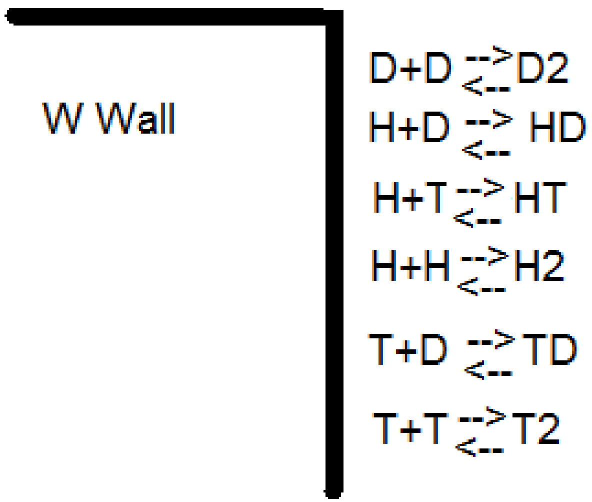
Diffusion Simulation :TMAP7

The TMAP Code was written at the Idaho National Engineering and Environmental Laboratory

The code let introduce heat and mass sources and drains.

Recombination/disotiation

Conventional *ratedep recombination formulates* the generation and release rate of molecules as the product of two atom concentrations at the surface and a recombination rate coefficient, often in Arrhenius form



Diffusion Simulation :TMAP7

Enclosures

Functional enclosures allow dynamic pressure and chemical reaction calculations to be included during the running of the problem. There may be diffusive flows of enclosure species to and from the surfaces

Traps

No traps has been taken in consideration in the simulations. But the coefficients that had been used in these simulations are experimental, so they had been calculated with traps in the tungsten.

LIMITATIONS

- There are limited and confused database on hydrogen isotopes transport parameters in W. Therefore, the same recombination and dissociation parameters have been used for H,D and T.
- Helium has been simulated independently with a different input, Helium does not has recombination/dissociation reactions in the surface
- TMAP7 is a 1D model

Diffusion Simulation :TMAP7

- **Transport parameters of hydrogen isotopes in W used for diffusion in TMAP7 model:**

	$D_0[m^2/s]$	E_d[KJ/mol]
Deuterium[1]	5.49×10^{-10}	10
Tritium[1]	5.34×10^{-10}	11.2
Hydrogen[2]	4.1×10^{-7}	38

$$D = D_0 \exp\left(\frac{-E_d}{RT}\right)$$

	$D[m^2/s]$
Helium[3]	10×10^{-10}

- **The recombination and dissociation parameters that have been used**

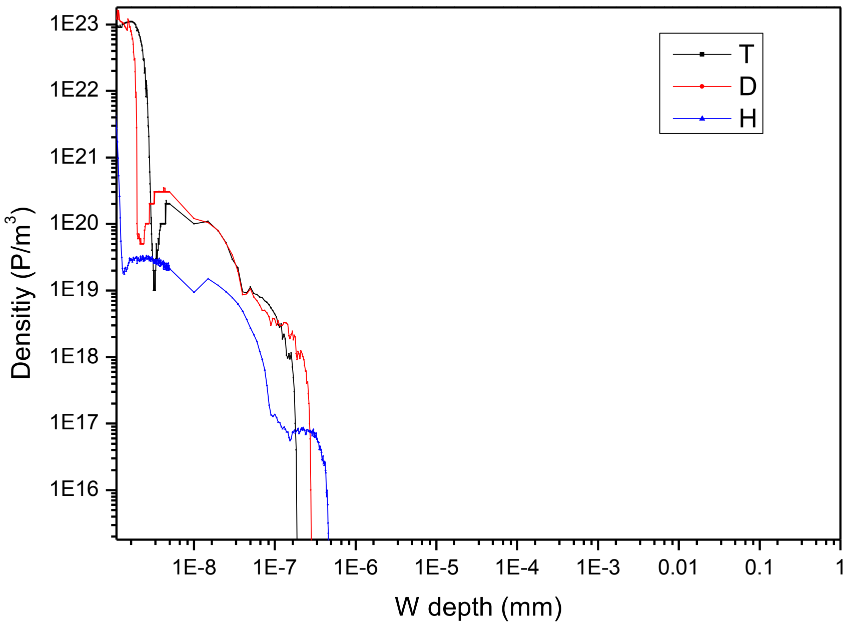
	K_{0r} $[m^4/s]$	E_r [KJ/mol]	K_{0d} $[molec/m^2Pa]$	E_d $[m^2/s]$
T_2,D_2,H_2,HD, HT,DT[2]	3.2×10^{-15}	112	1.02×10^{34}	314

$$K_{r/d} = K_{0r/d} \exp\left(\frac{-E_{r/d}}{RT}\right)$$

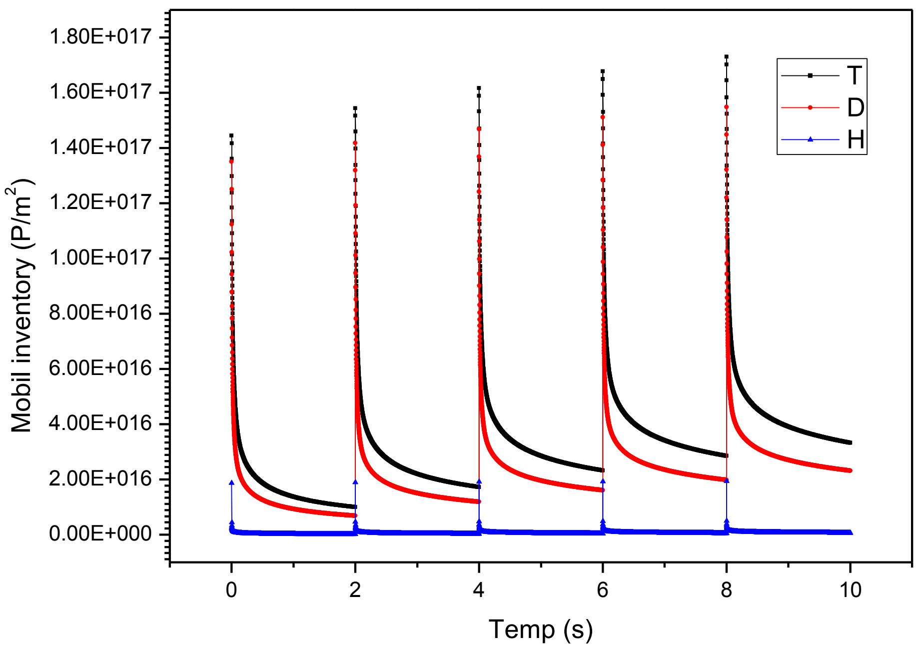
1 Hydrogen isotope diffusive transport parameters in pure polycrystaliine tungsten G.A.Esteban
2 A recompilaiton of tritium-material interaction parameters in fusion reactor materials. F.Riter.
3 Helium behaviour and vacancy defect distribution in helium implanted tungsten A. Debelle

Results

Initial distribution profile after 1 pulse.



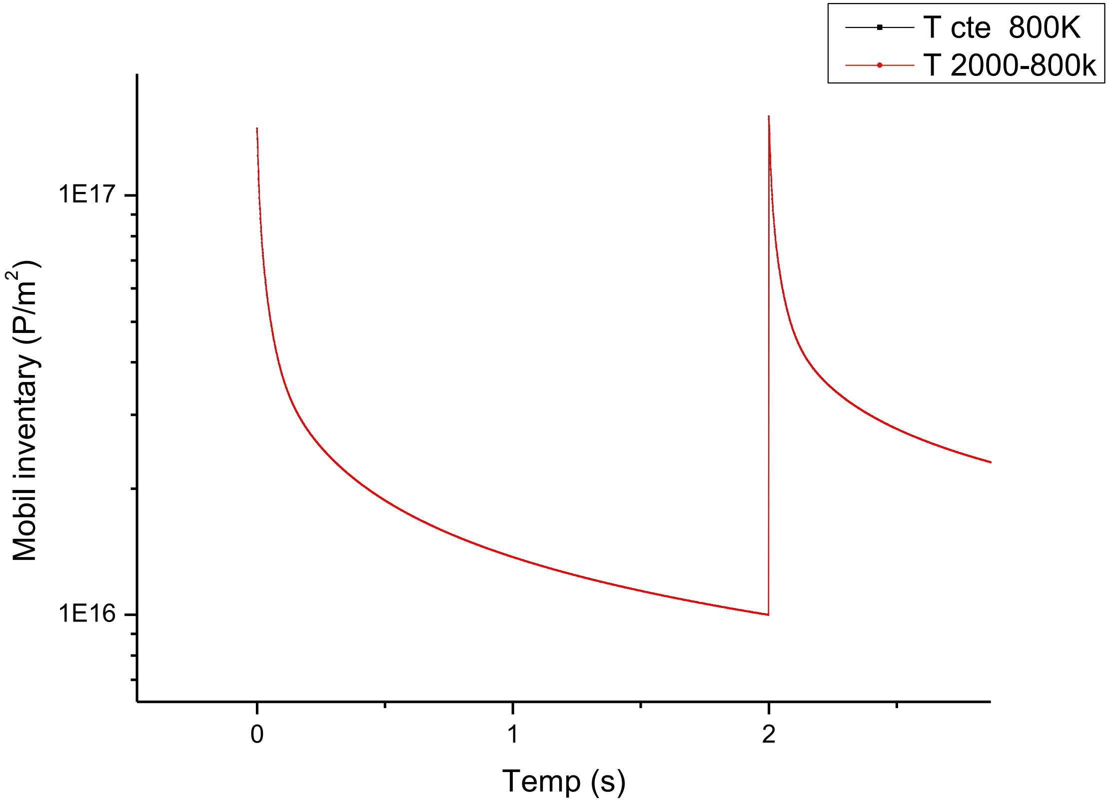
Mobil inventory (10s).



Isotope	Particles to W per pulse [P/m²]	% Particles lost after 10 seconds [P/m²]
H	1.880×10^{16}	99.26%
D	1.350×10^{17}	96.57%
T	1.445×10^{17}	95.4%

Results

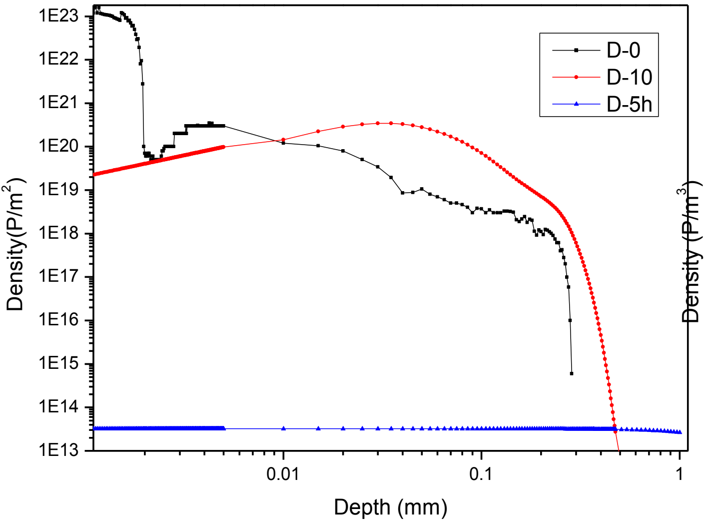
Temperature effect



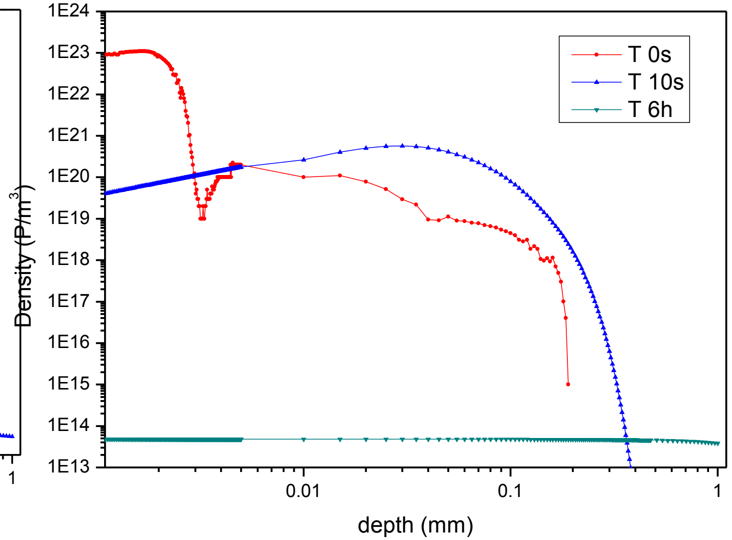
For this simulations there is not changes with the temperature

Results

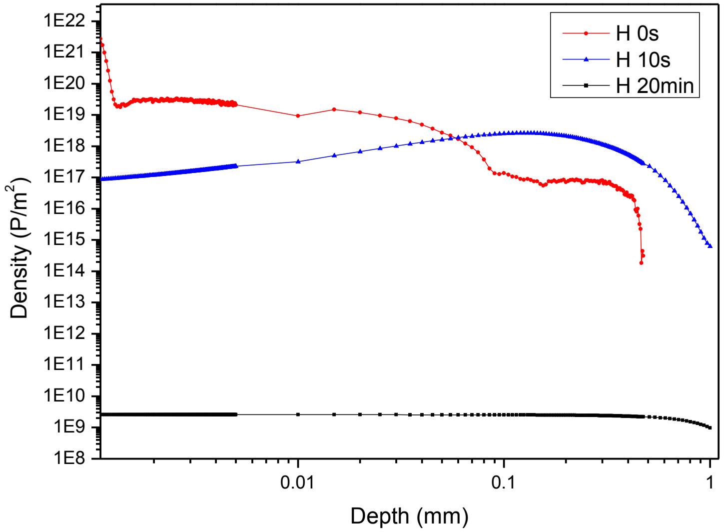
Deuterium distribution profile with time



Tritium distribution profile with time



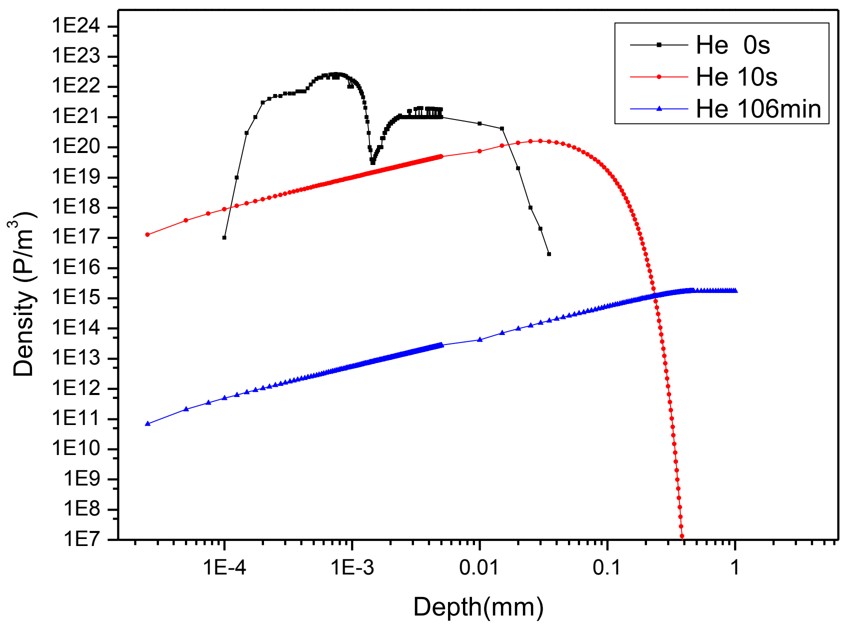
Hydrogen distribution profile with time



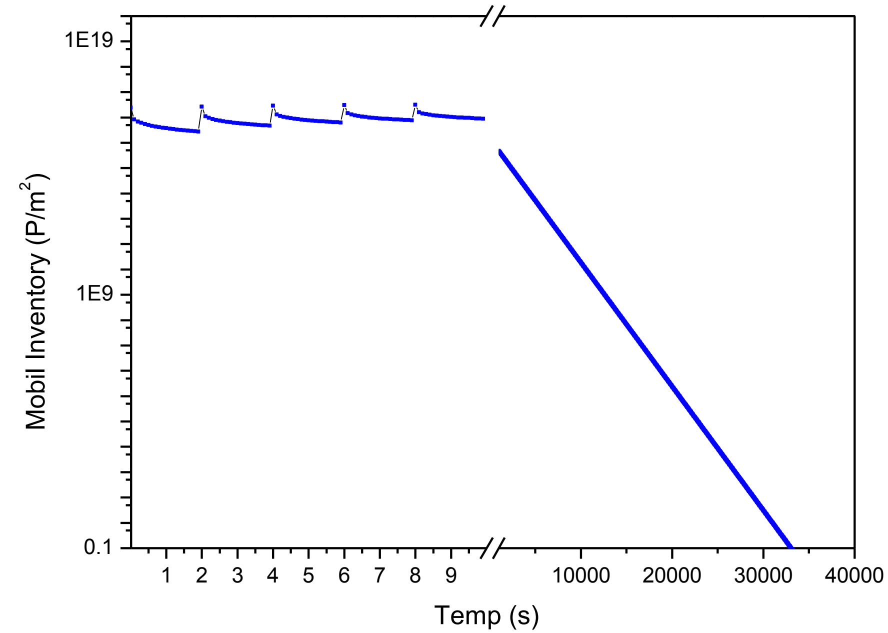
Isotope	Particles T= 0s [P/m²]	Particles after 10 seconds [P/m²]	Particles [P/m²]
H	$1.880x10^{16}$	$6.996x10^{14}$	2.004E6 (20 min)
D	$1.350x10^{17}$	$2.316x10^{16}$	3.064x100 (5h)
T	$1.445x10^{17}$	$3.325x10^{16}$	4.471x100 (6h)

Results

Helium distribution profile with the time



He mobil inventory (10s)



	Particles T= 0s[P/m²]	Particles after 10 seconds [P/m²]	Particles lost after 106min [P/m²]
He	2.4085×10^{16}	8.7982×10^{15}	3.0966

Conslusions and Future plans.

CONCLUSIONS

- After 10s the 90-99% of particles are released from the tungsten wall, mostly, towards the chamber. No element crosses the tungsten wall to the cooler.

- With $1x10^{22}$ p/m^2 of He inside the W wall, He starts occasioning damages in the material. For case HiPER4a that is not a problem.

Element	Particles T= 0s [P/m^2]	Particles after 10 seconds [P/m^2]	Particles [P/m^2]
H	$1.880x10^{16}$	$6.996x10^{14}$	$2.0x10^{6}$ (20 min)
D	$1.350x10^{17}$	$2.316x10^{16}$	$3.1x10^{10}$ (5h)
T	$1.445x10^{17}$	$3.325x10^{16}$	$4.5x10^{10}$ (6h)
He	$2.4085x10^{16}$	$8.7982x10^{15}$	3.1 (106 min)

FUTURE PLANS

•In this study traps have not been calculated; in future investigations different traps must be studied for HiPER project and its working conditions.

• A wall of steel or other structural material must be joint to the W wall. It is necessary to know the behavior of the different elements with the second wall, and see if there is any problem with tritium, which is radioactive.

• Another enclosure should be added in TMAP7 to be able to simulate the pump that goes inside the chamber. This pump will maintain the chamber free of isotopes and their products. It must be calculated the quantity of Tritium release to the coolant side after longer periods of time.

THANK YOU VERY MUCH FOR YOUR ATTETION