Status of the Target study

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Presented by Marco Ciotti

Merge of 3 presentations:
- -P. Agostini: system engineering
- -M. Ciotti: concepts development
- -C. Petrovich: Neutron calculations

Outline

-Target concepts and their neutron production efficiency

(neutron calculations performed by C. Petrovich);

-Target reference solution: Rastering& Diffusion systems

-System pre-engineering (thermo- mechanical aspects will be presented

on Thursday by P.Agostini)

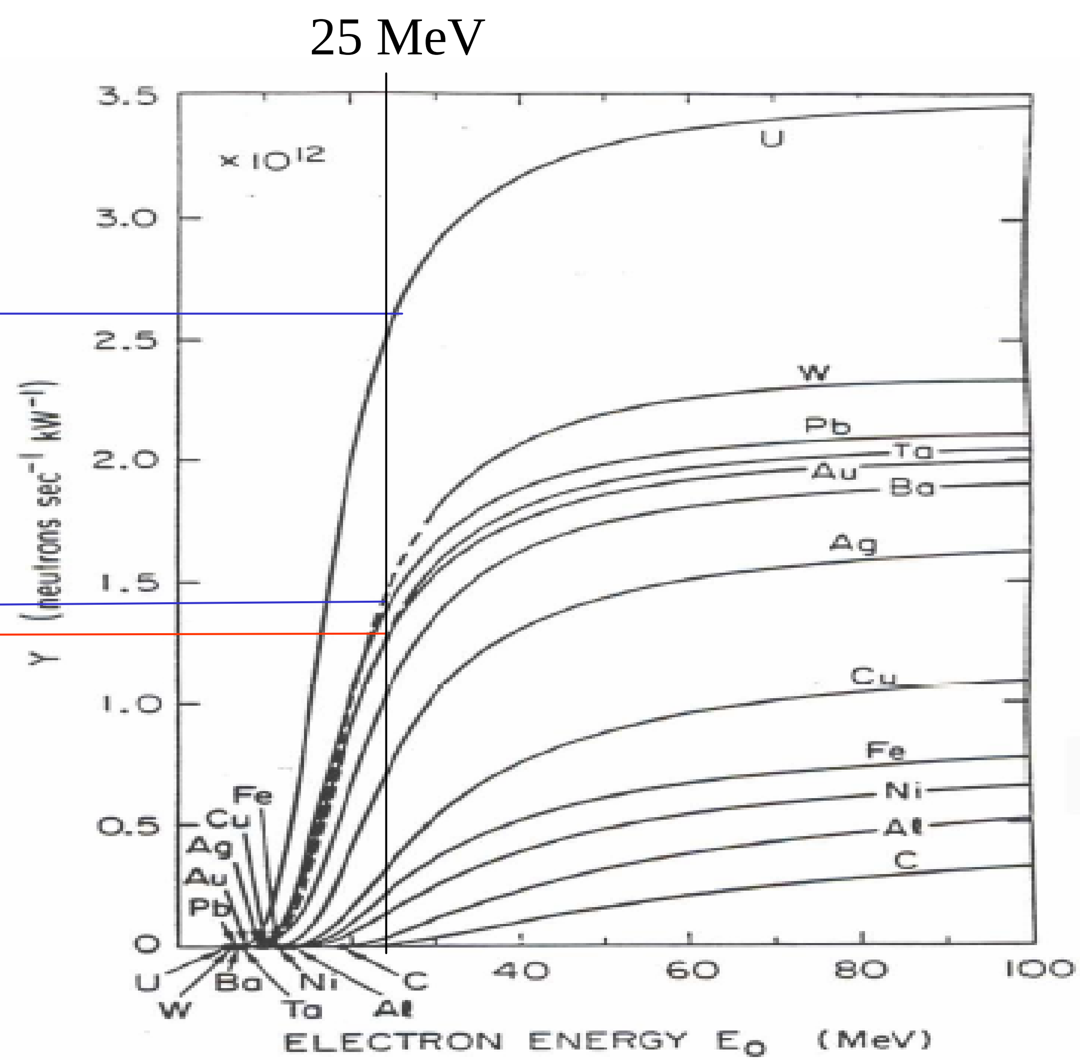
Material choice

Neutron yields from infinitely thick targets [Swanson, 1979]

Neutron source of the order of 10^{14} n/s

R(U/W) ≈ 1.75

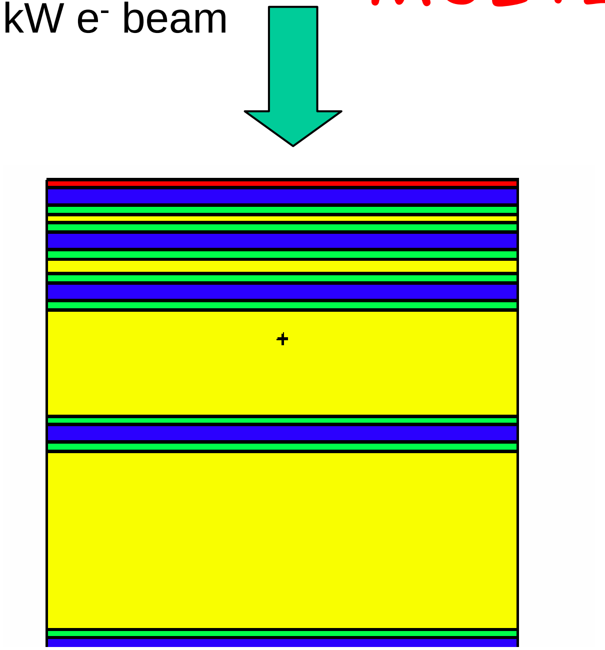
R(U/Ta) ≈2



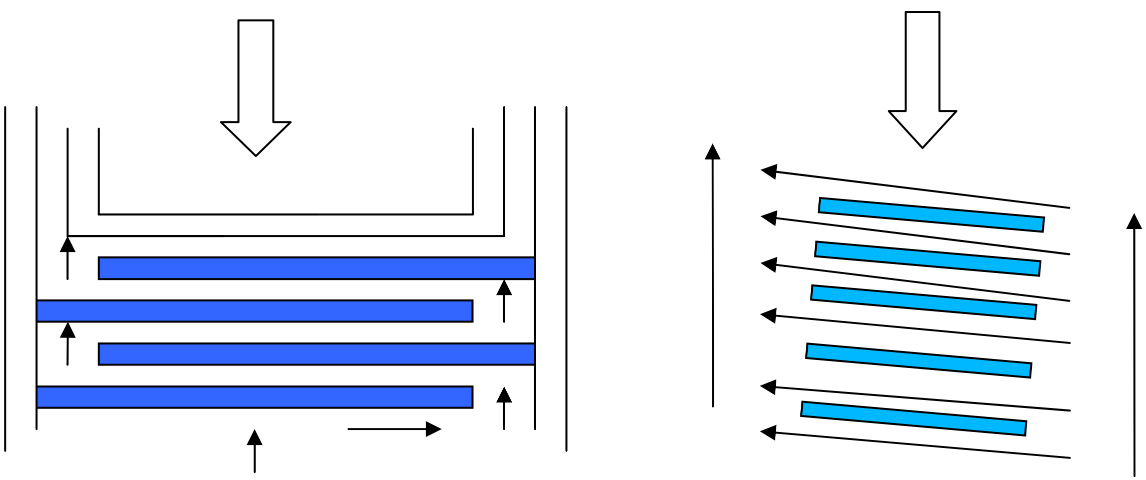
From MCNP simulations n/s	
Infinite uranium	~9.8E13
Infinite tungsten	~4.0E13

MULTI-PLATE TARGET

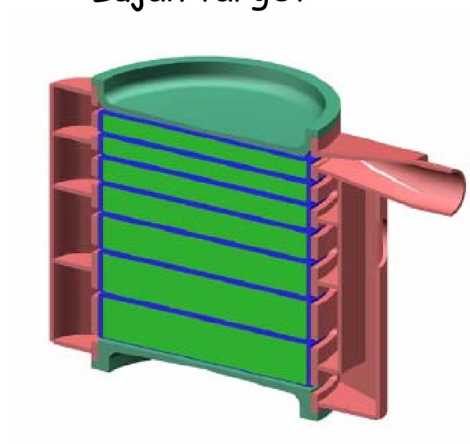
30 kW e^- beam



- **From thermo-hydraulic criteria: 6 kW / disk**
- gaussian beam ($s_x = s_y$=1.33 cm). 95% of the beam in D=65 mm. For the power density in the first disk: max/avg ~ 3;
- window: 1mm of Ta
- 4 uranium disks with thicknesses: 1mm +1.7mm +12mm +20mm
- 1 mm of Al cladding
- 2 mm of H_2O between the U disks



Lujan target



Concept of Water Cooled Multi-plates Target with Serial and with Parallel Flow

Results by means of MCNPX for the multi-plate

Power in the disks:

•Window (1 mm of Ta):	3.1 kW
•disk n.1 (1 mm of U + Al cladding):	6.6 kW
•disk n.2 (1.7 mm of U + Al cladding):	6.1 kW
•disk n.3 (12 mm of U + Al cladding):	5.7 kW
•disk n.4 (20 mm of U + Al cladding):	1.7 kW
•in the total layers of water:	1.5 kW

- Total power in target is 24.7 kW and not 30 kW (γ and e^- escape).

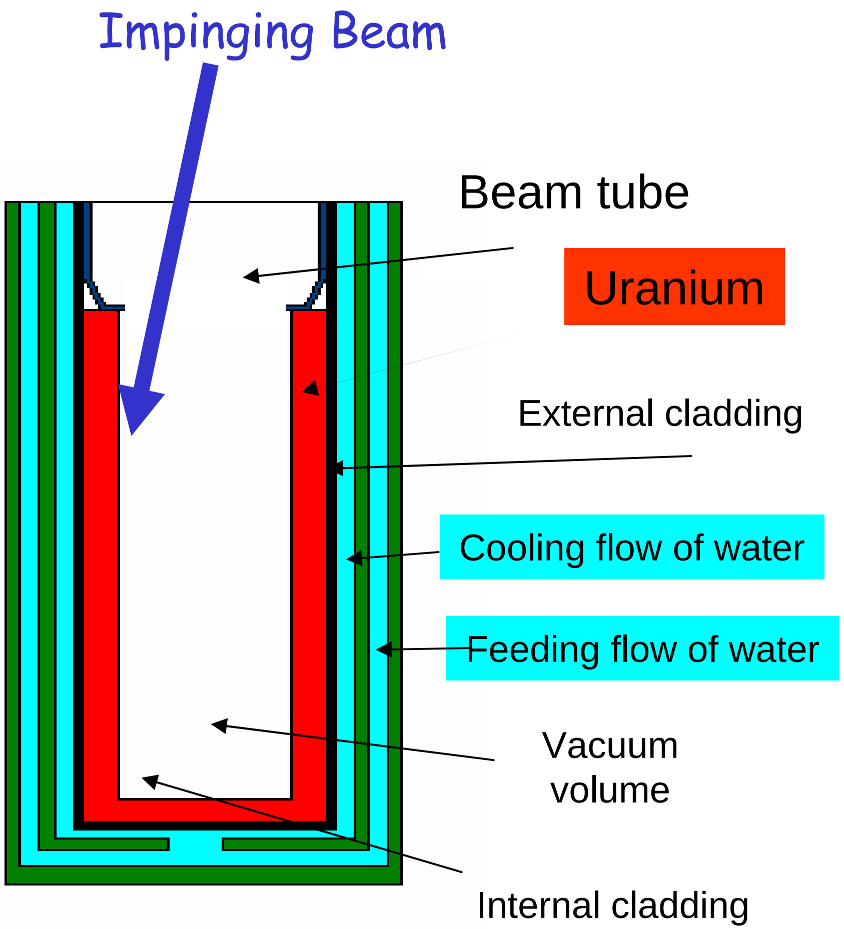
-Neutron source: 5.7E13 n/s

95% from photonuclear, 5% from neutron fission

•**About the same neutron source for**: depleted uranium, natural uranium, SiCrAl U alloy (Al 700 ppm, Fe 300 ppm, Si 120 ppm, Cr 80 ppm, density 18.7 g/cm^3)

Cilyndrical Target Concept

- Easy to manufacture
- Maximum neutron production



Motivations for the Target Selection

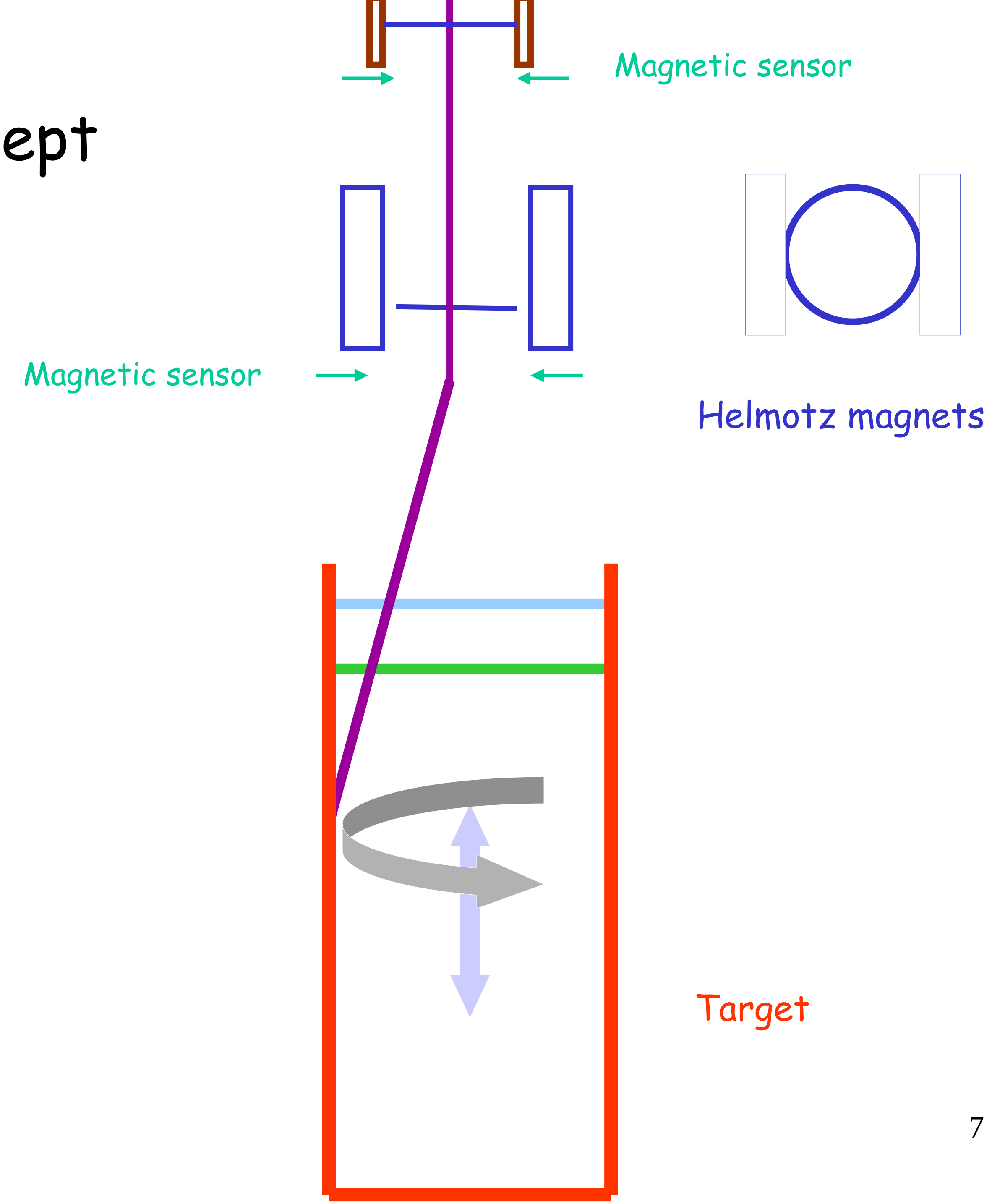
- High neutron production (more than 7E13 n/s)
- large and suitable surface for water cooling (a vertical cylinder of 370 mm height and 71mm diameter),
- homogeneous power distribution along the walls
  - Beam steering option: possibility to engineer the **power distribution** functions
  - Beam diffusion option: Acceptable homogeneity
- Possibility to obtain the function of best coupling to the core in case of beam steering option
- Possibility to perform thermal hydraulic tests in full scale and full power

Neutron production

	Neutrons/s (30 kW, 25 MeV)	**Neutrons/s (20 kW, 25 MeV)**
Infinite uranium	~9.8E13 including fiss. ~8E13 from (γ,n)	~6.5E13 including fiss. ~5.3E13 from (γ,n)
Infinite tungsten	~4.0E13 (tot net production)	~2.7E13 (tot net production)
Uranium cylinder (r=3.25cm, h=8cm)	~8.0E13	~5.3E13
TRADE-13c200 with Ta	~3E13	~2E13
TRADE-13c200 with U	~7.4E13	~4.9E13
Multi-plate target Backup solution	~5.7E13	~3.8E13
Hollow uranium cylinder Reference solution	**~7.8E13**	~5.2E13

Rastering Concept

Very reliable
Easy to check



Rastering dimensioning
(order of magnitude)

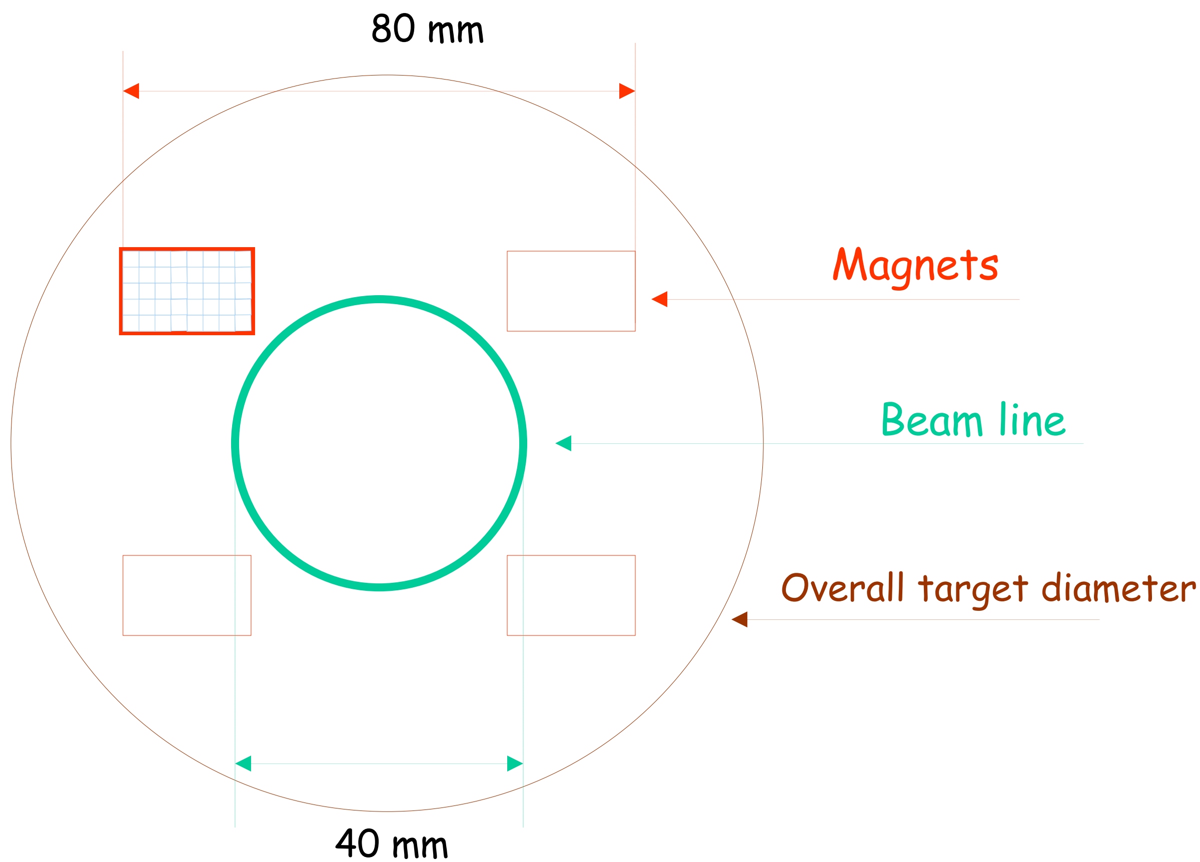
Using Biot-Savart with $\gamma = 50$, $\Theta = 5°$ deflection angle (30 cm above the target top)

Few hundreds W
Power dissipation

$L \approx mH$
$V = L dI/dt$

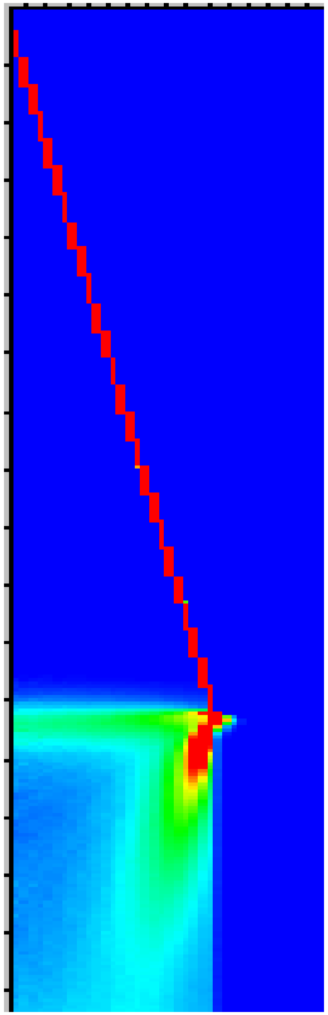
$dt \approx ms$

$V \approx$ tens of Volts



- 2.4 ° incident beam **10 kW** in the bottom U plate.

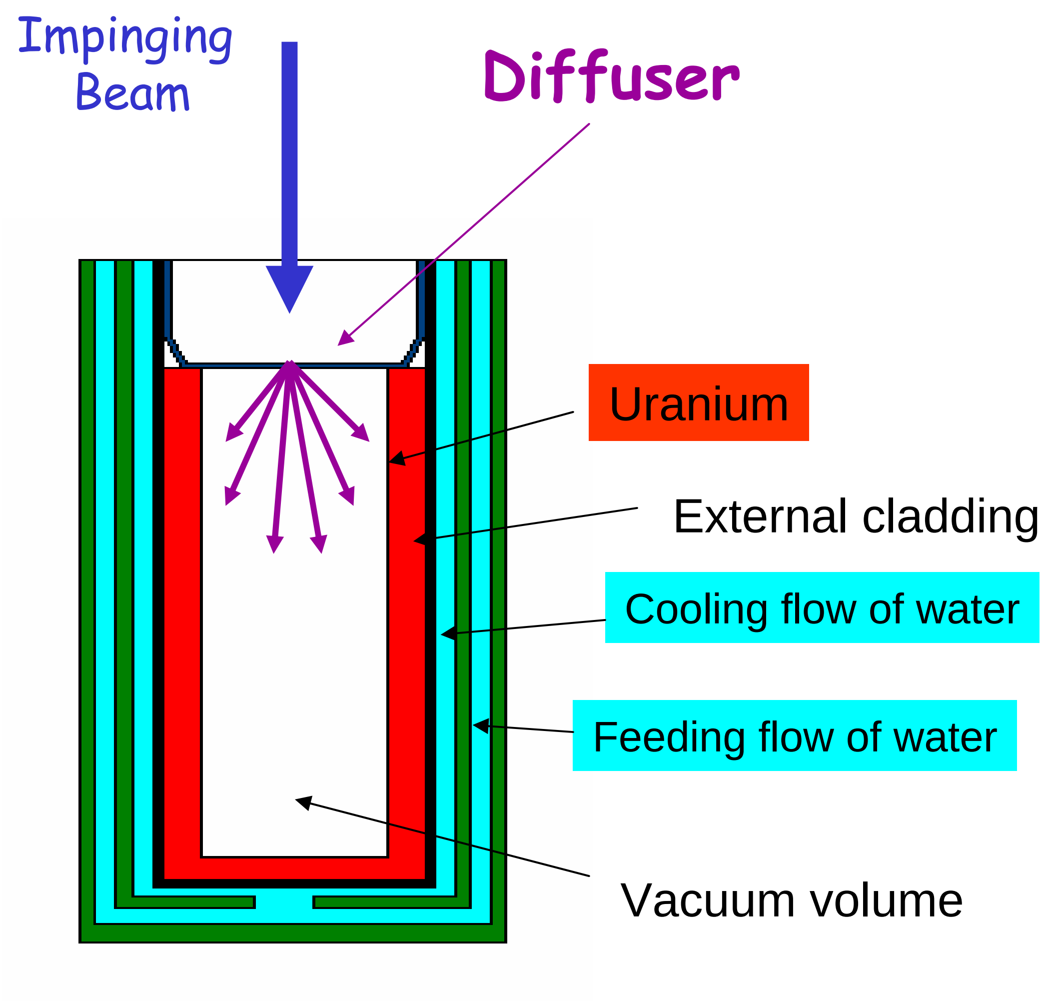
- 14.3 ° instead of 2.4 ° the power deposited is **0.59 kW**



- beam impinging at 3/4 of the cylinder height (= 35.2 cm), 2.4° angle
- 0.5 mm of Al inner cladding (r_{int}=26 mm);
- 15 mm thickness of U hollow cylinder (r_{int}=26.5 mm; r_{ext}=41.5 mm);
- 0.5 mm of Al external cladding (r_{ext}=42 mm);
- uranium plate at the bottom of the target (thickness and shape to be fixed).

	Power deposited **30** kW, 25 MeV, **2.4**° incident beam	Power deposited **30** kW, 25 MeV **14.3**° incident beam	Power deposited **20** kW, 25 MeV **2.4**° incident beam
Inner cladding	4.4 kW	2.4 kW	2.9 kW
U cylinder	15.1 kW	25.3 kW	10.1 kW
Bottom U plate	9.5 kW	0.59 kW	6.3 kW
TOTAL	**29.2 kW**	**28.3 kW**	**19.5 kW**

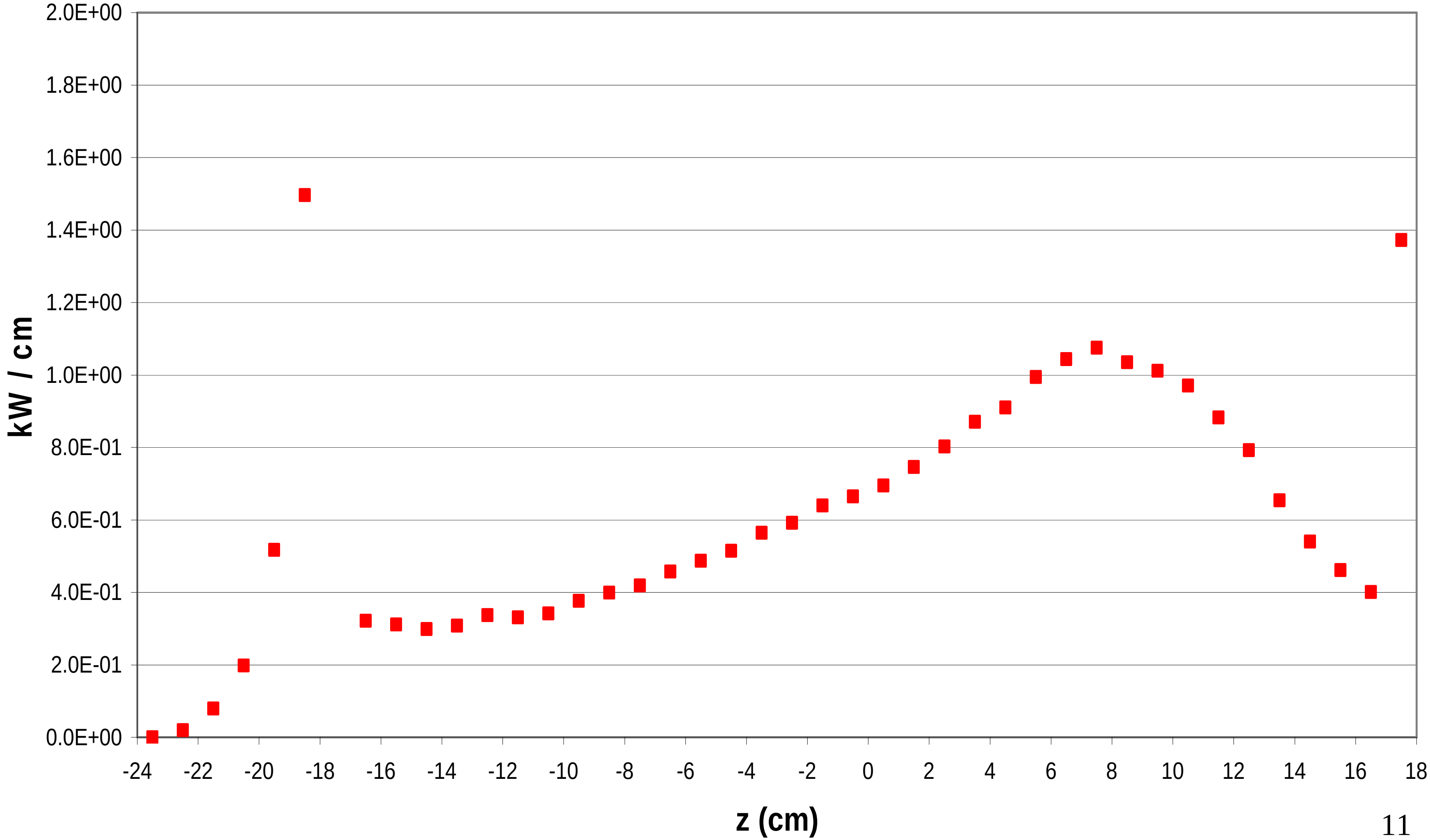
Diffuser concept



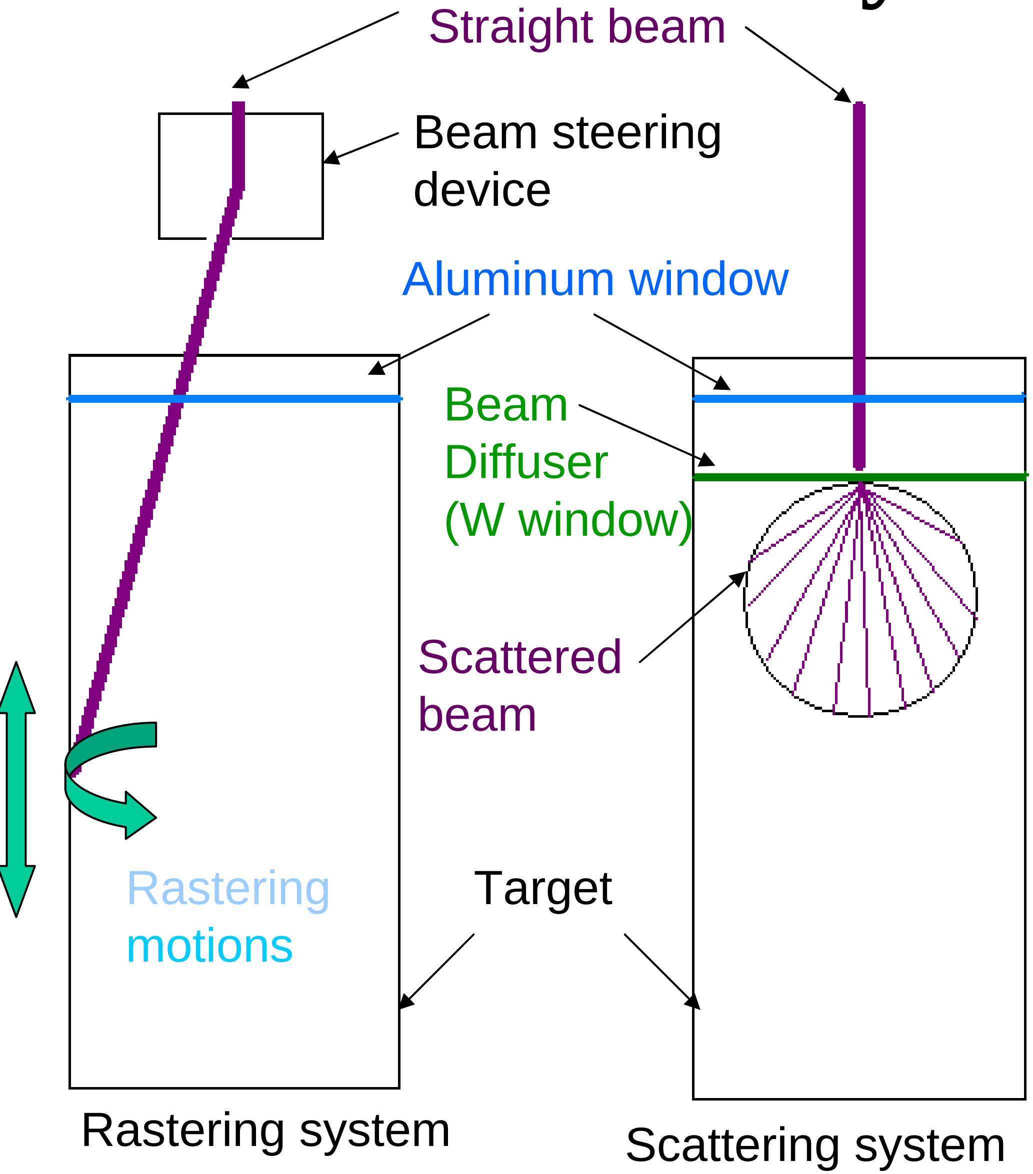
	(30 kW, 25 MeV beam) Power deposited	(20 kW, 25 MeV beam) Power deposited
Ta window (0.3 mm)	0.73 kW	0.49 kW
U cylinder	21.7 kW	14.5 kW
Bottom U plate	6.0 kW	4.0 kW
Others	0.4 kW	0.3 kW
TOTAL	**28.8 kW**	**19.2 kW**

- The window spreads the electrons and the gammas along the U wall.
- Neutron source: 7.8E13 n/sec (<2% variation with uranium thickness of 10 mm).

Axial power distribution along the uranium hollow cylinder for a 30 kW, 25 MeV electron beam (The beam comes from the right side. The tantalum window is at z=17.6cm. The bottom of the cylinder at z=-17.6cm).



PROs and CONs of the rastering system



PROs

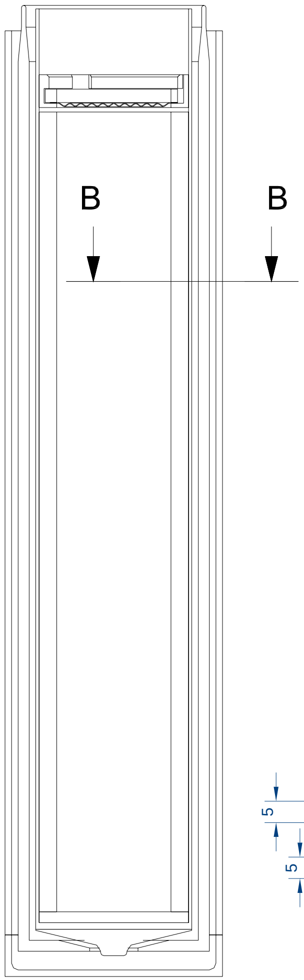
- The technology is very easy
- allows to optimize the power deposition inside the target.

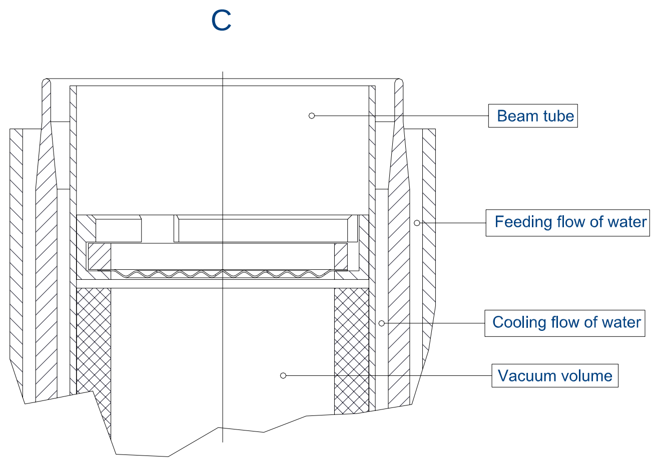
CONs

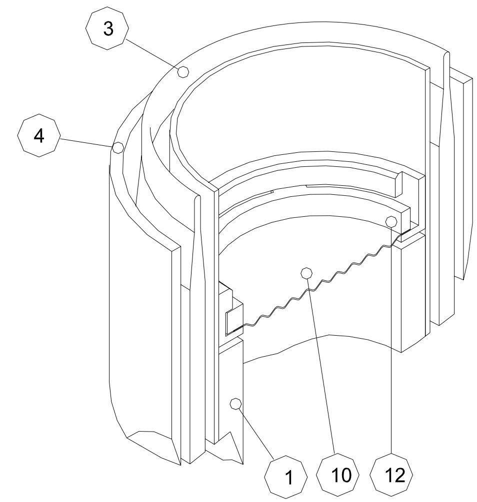
- The rastering magnets will occupy a certain volume, but some driving magnets are necessary in any case.
- The rastering magnets need to be placed below the water level, close to the core

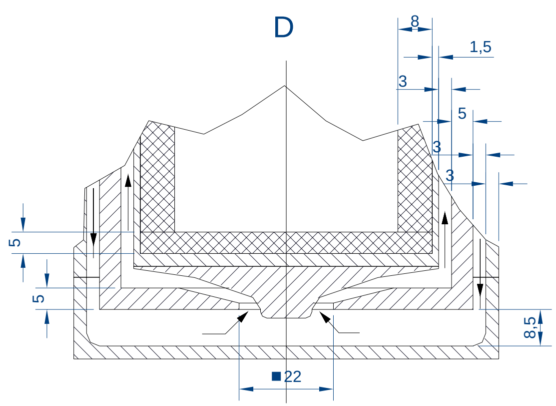
ENEA

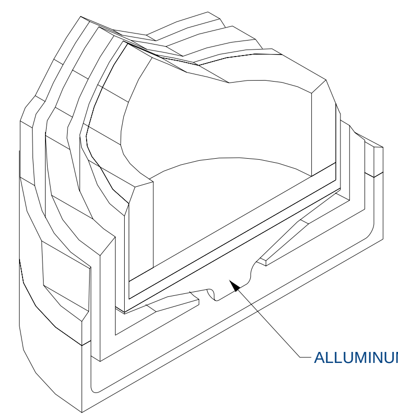
General Assembly of Reference Solution (without rastering)

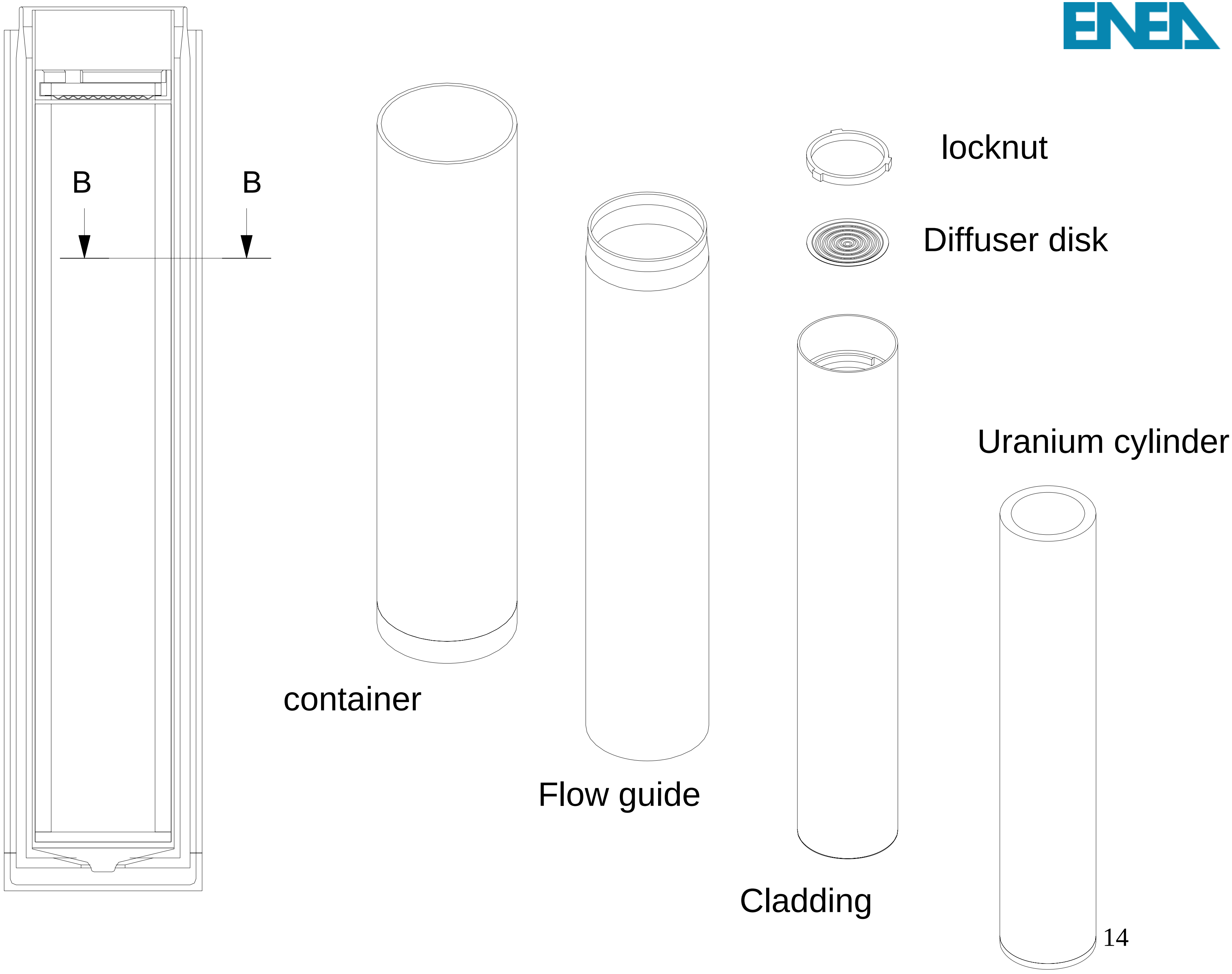








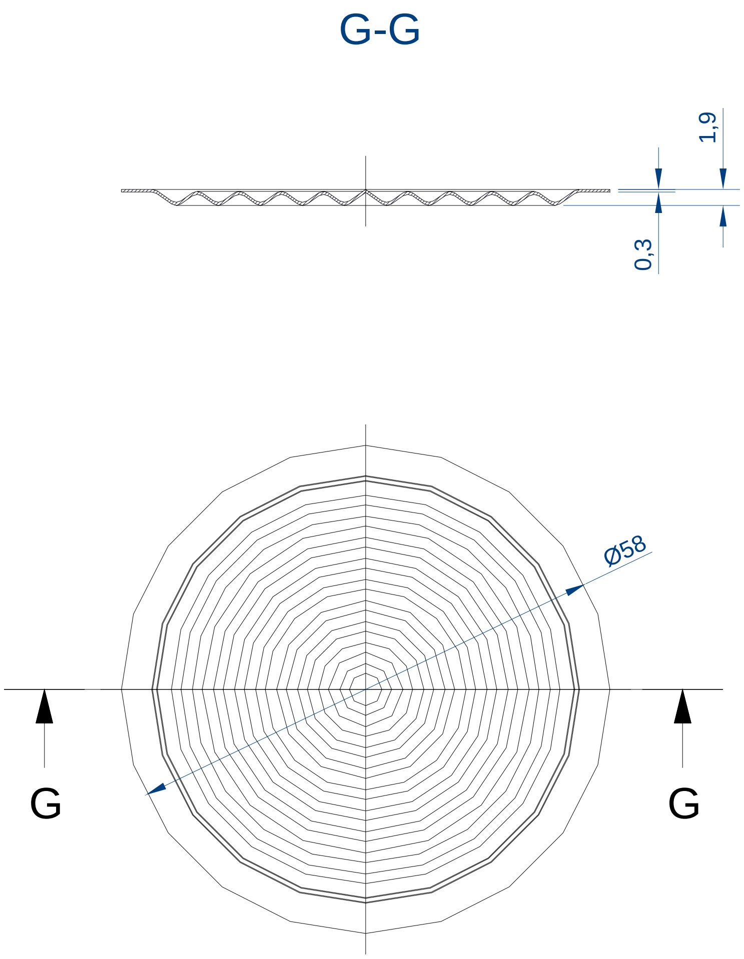



B
B
locknut
Diffuser disk
container
Flow guide
Cladding
Uranium cylinder

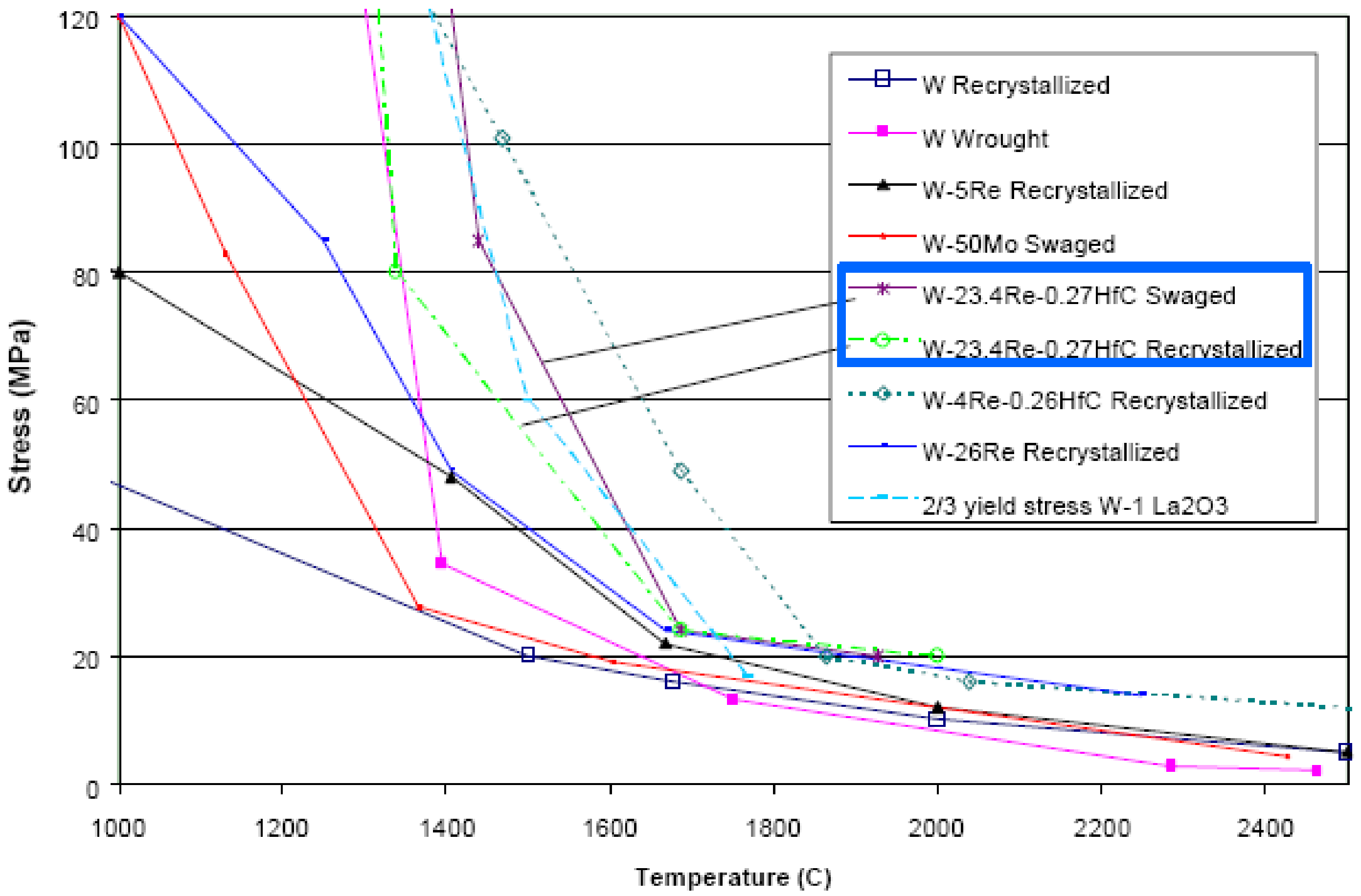
Diffusion Disk

The beam diffusion option relies on the diffusion disk. The material is W-23.4Re-0.27HfC which associates:
-High operating temperature
-Good resistence to the irradiation embrittlement
-Good neutron production rate
-Good diffusion of electrons
Two possible shapes are envisaged:

- Bellow type
- Flat radiating disk

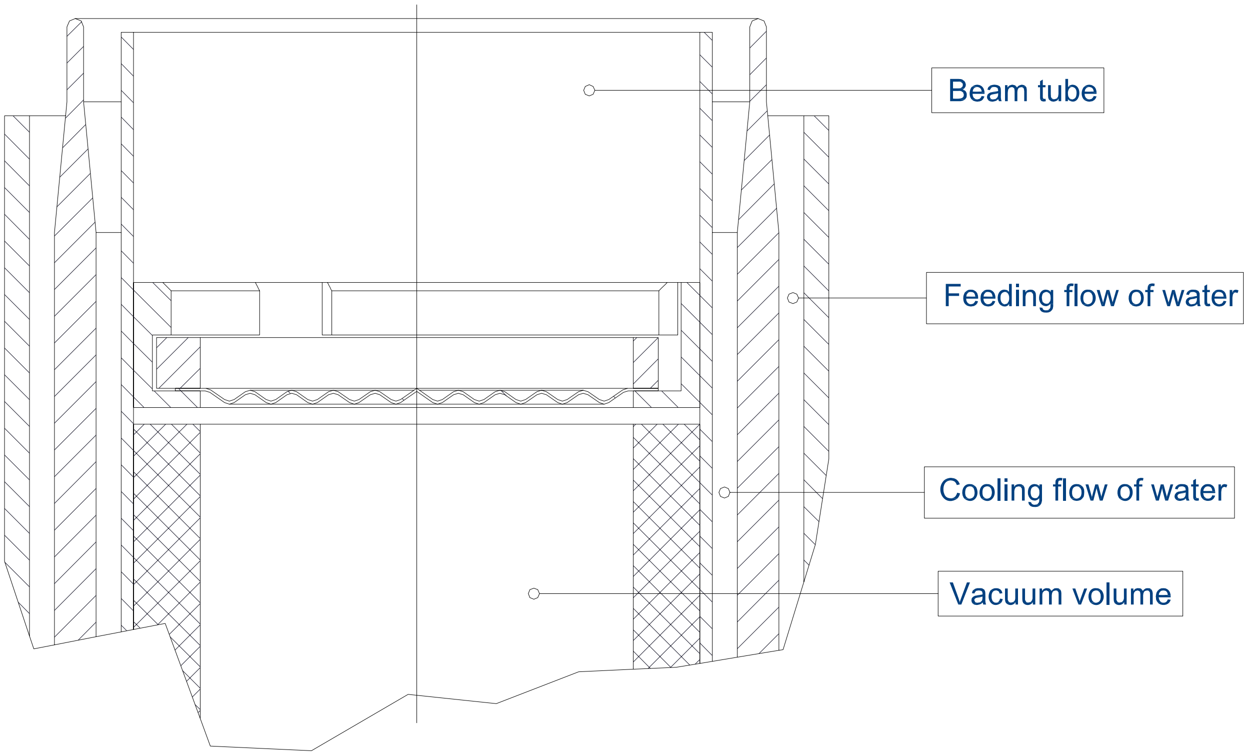


Comparison of High Temperature Design Stress Limits of W-Alloys



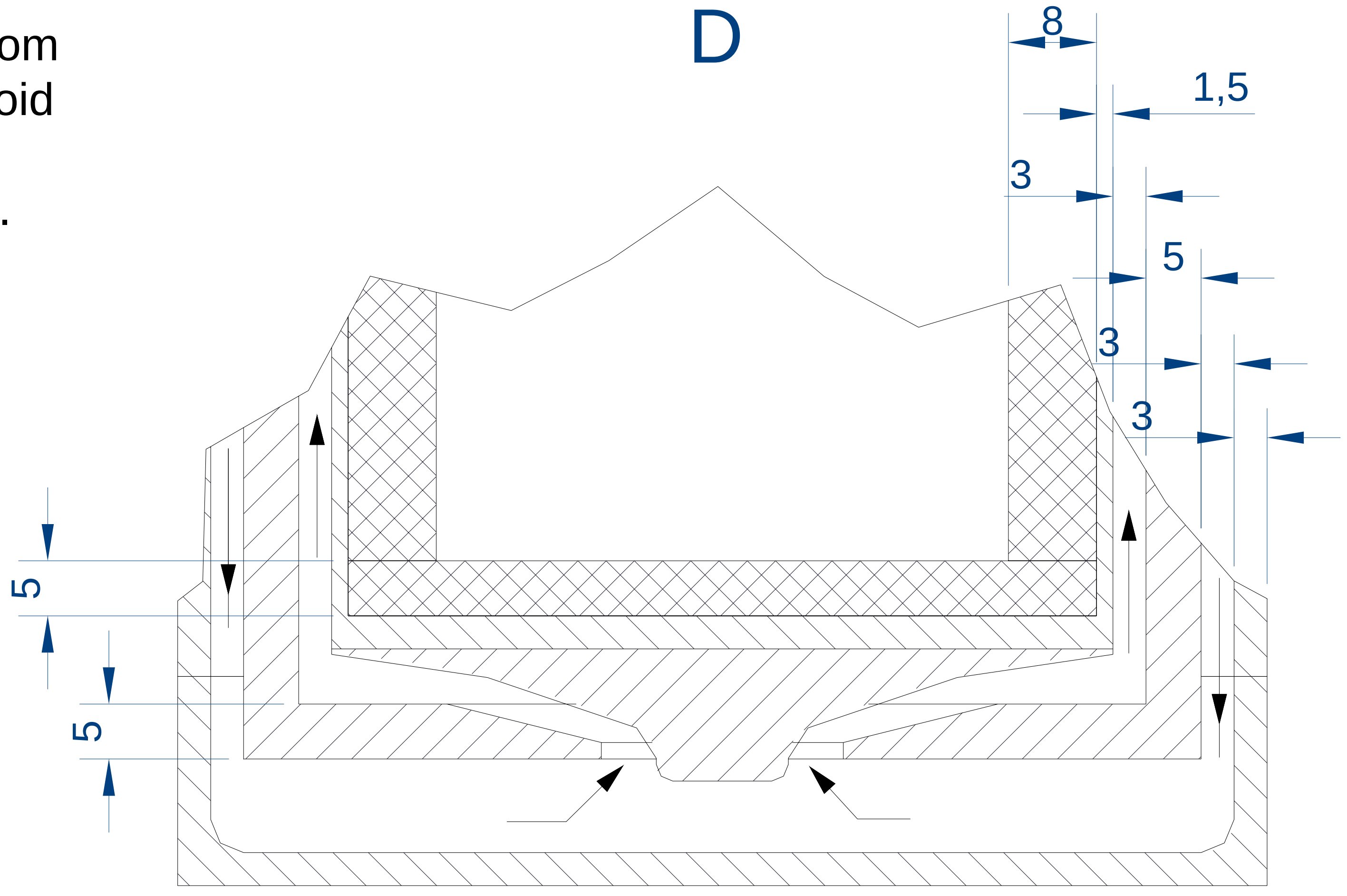
Cladding

Cladding is necessary to avoid direct contact between Uranium and cooling water
In this case has also structural functions, therefore AISI 316 would be the best choice.
This item has to be discussed with the manufacturer
The inner cladding would reduce the neutron conversion efficiency due to the low grazing angle and long path of electrons inside it.



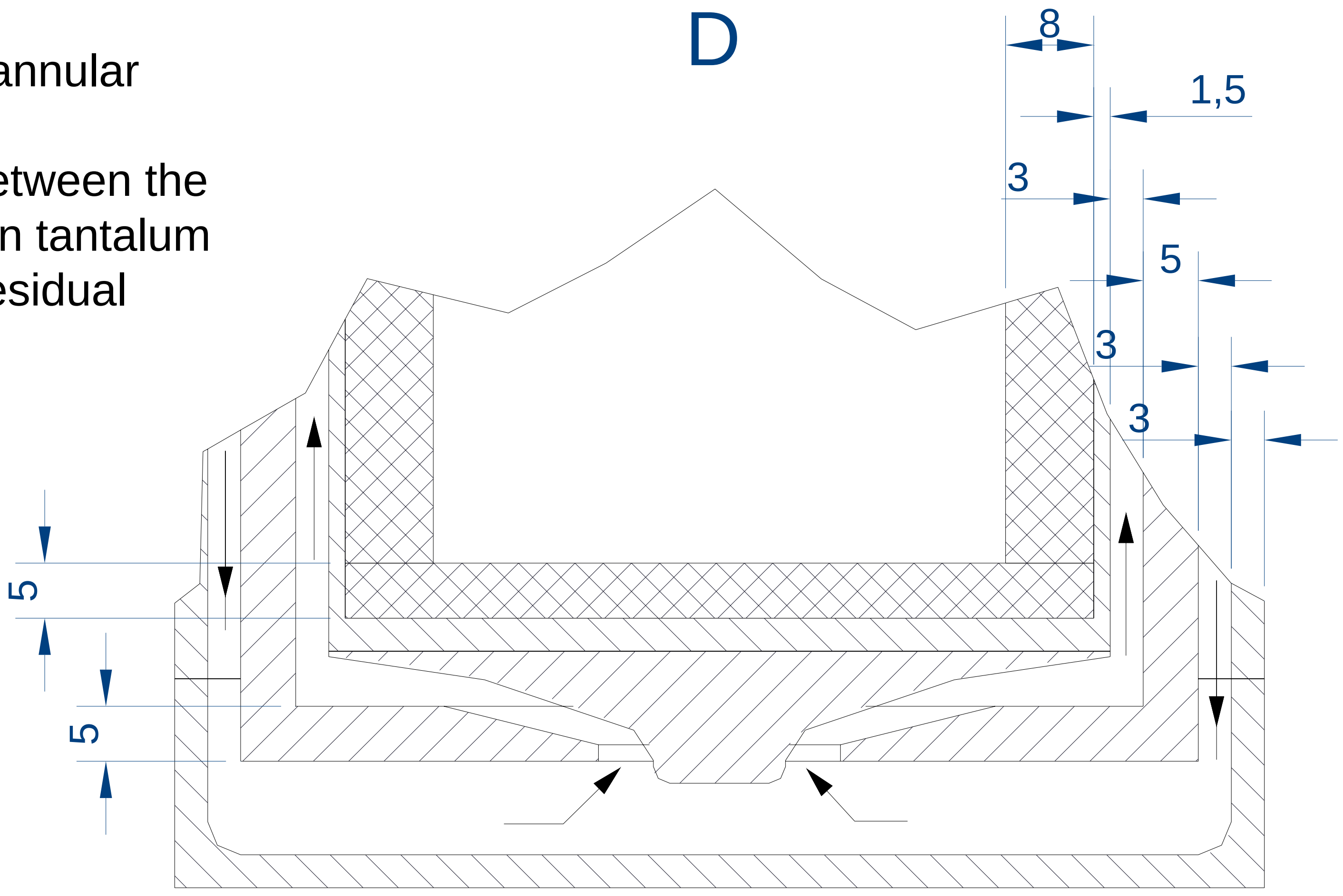
Cladding

A suitably shaped Aluminum body will be placed below the bottom cladding to avoid stagnation of vapor bubbles.



Concentric flow channels

In order to minimize the radial space, the feeding water
Comes from an annular external channel
The separator between the two channels is in tantalum
To convert the residual electrons



Conclusion

- A reference solution has been chosen
- The target design is progressing
- The cylindrical Uranium target assures a high e/n conversion efficiency
- The concept of the target backup solution has been analyzed
- The feasibility of the rastering system has to be checked in terms of available space
- The diffusing window could replace or join the rastering systems.
- The feasibility of the diffusing window must be checked in terms of life span.