Status of the septa program for the CLIC Test Facility 3

Julio.lucas@elytt.com

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Introduction. Status of the program

ELYTT Energy S.L. has performed in behalf of Ciemat, the conceptual design of two types of septa for the injection-extraction in the CR ring for the CTF3 facility.

A manufacturing contract has been awarded to ELYTT Energy for the fabrication of the 4 units.

The conceptual design phase is now finished. Manufacturing drawings of all components (almost) and tooling are ready.

We have offers for the manufacturing of the components.

Basic parameters of the septa

	Thin septum	*Thick septum*
Operating current	1975 A	1975 A
Magnetic length	782 mm	650 mm
Physical length	900 mm	692 mm
Integrated field	48 mT.m	161 mT.m
Septum thickness	2 mm	11.4 mm
Gap heigh	40 mm	40 mm
Gap width	70 mm	90 mm

Thin septum global description I

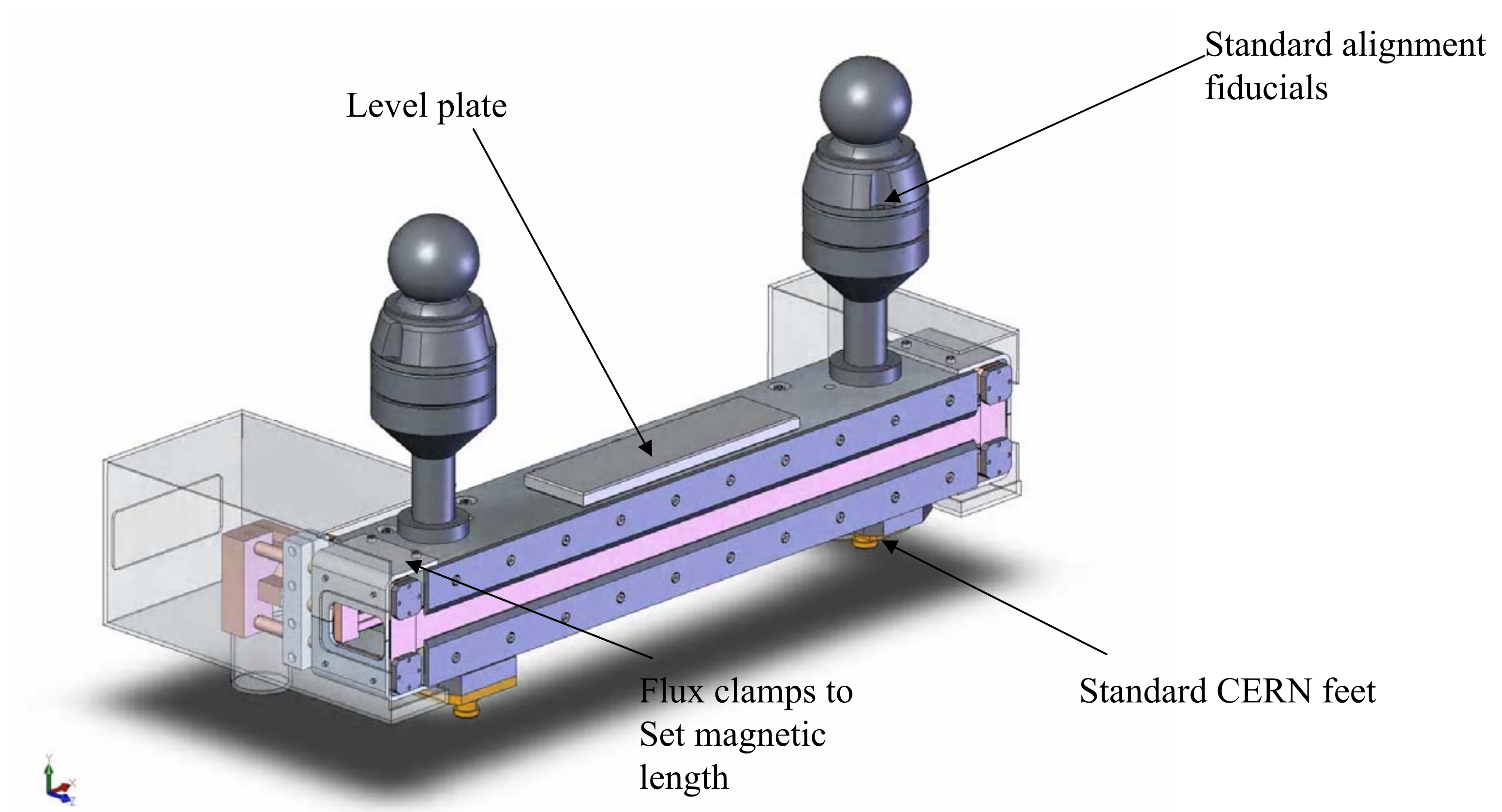
For the thin septum, we have chosen a design with a septum plate made of a 1.5 mm thick Glidcop sheet and two cooling tubes brazed at the top and bottom of the septum plate. The septum plate will be insulated by 2 layers of 0.1 mm thick polyimide

No reinforcement steel plate brazed to the copper sheet is foreseen. The cooling tubes allow the insertion of a extracted beam tube of diameter

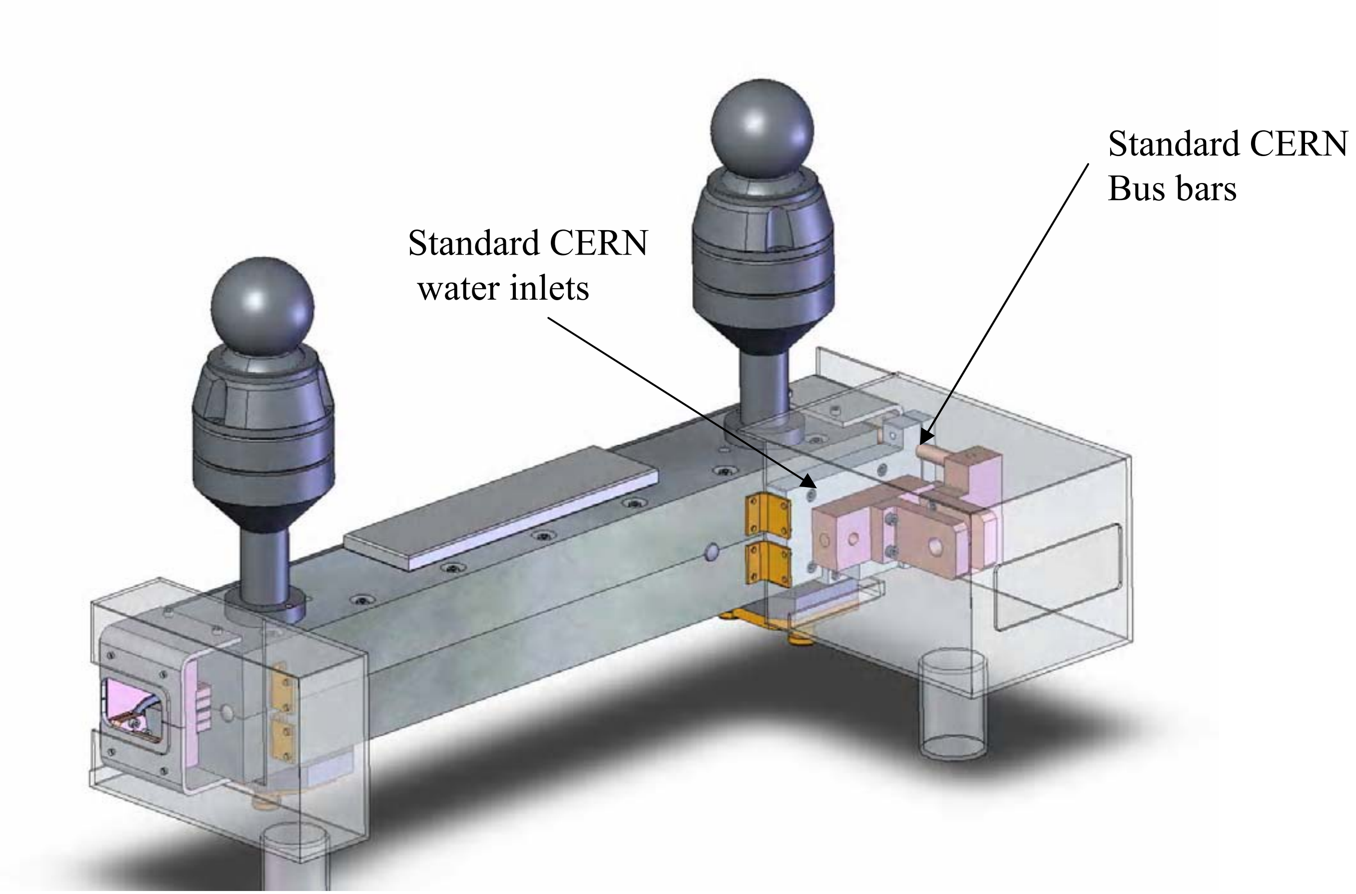
The circulating beam tube is modeled as a cylinder of diameter 44 mm

After the Technical design Review of June it was decided to aim at the final magnetic length from the design (no magnetic length trimming). A set of flux clamps was added to achieve it.

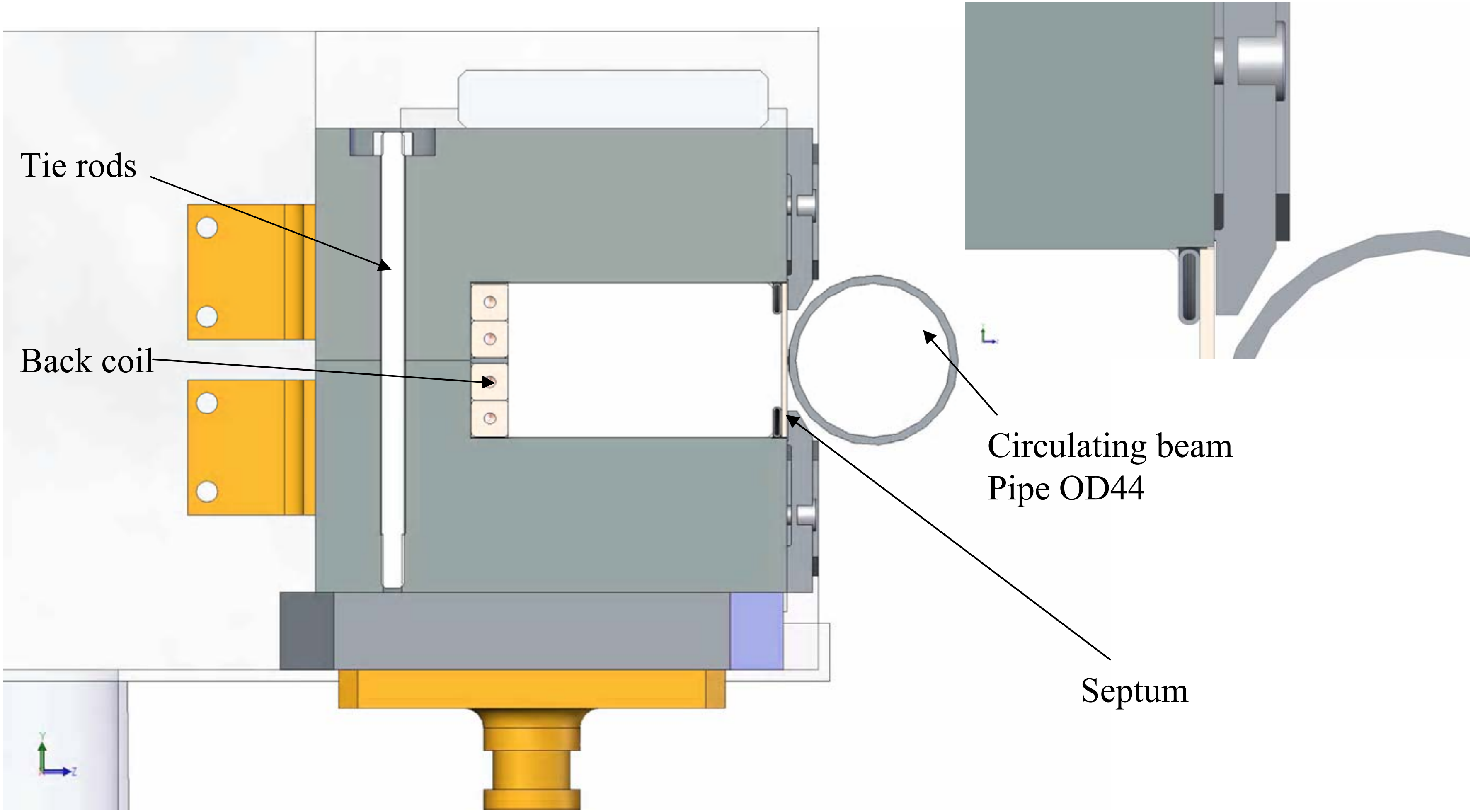
Thin septum global. New features I



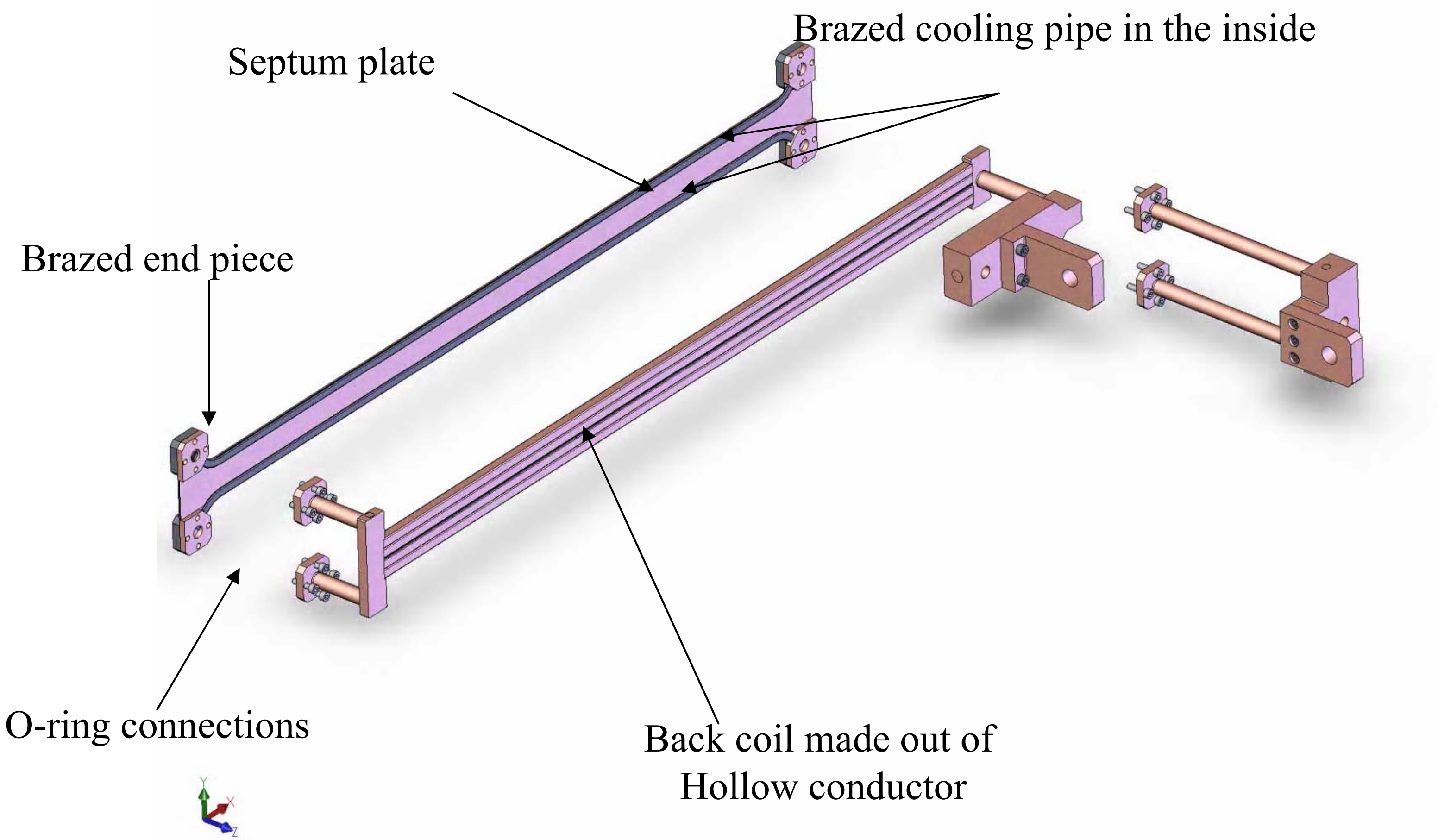
Thin septum global description. New features II



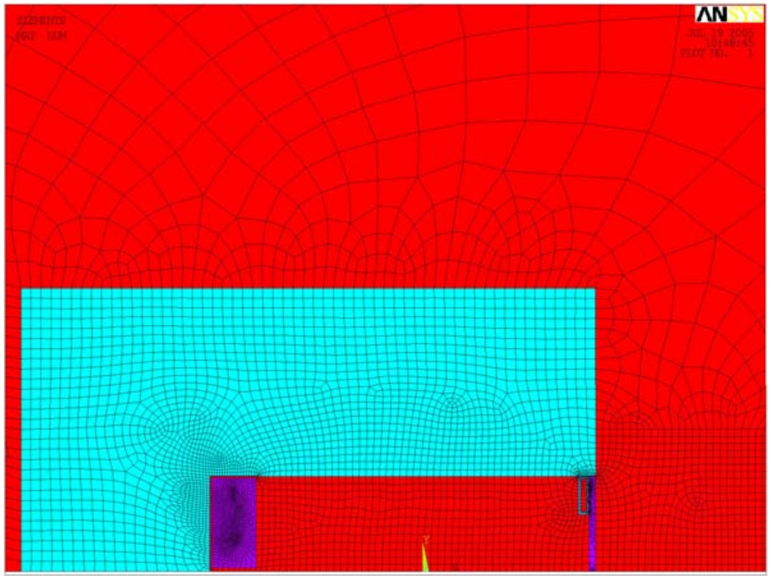
Thin septum global description III



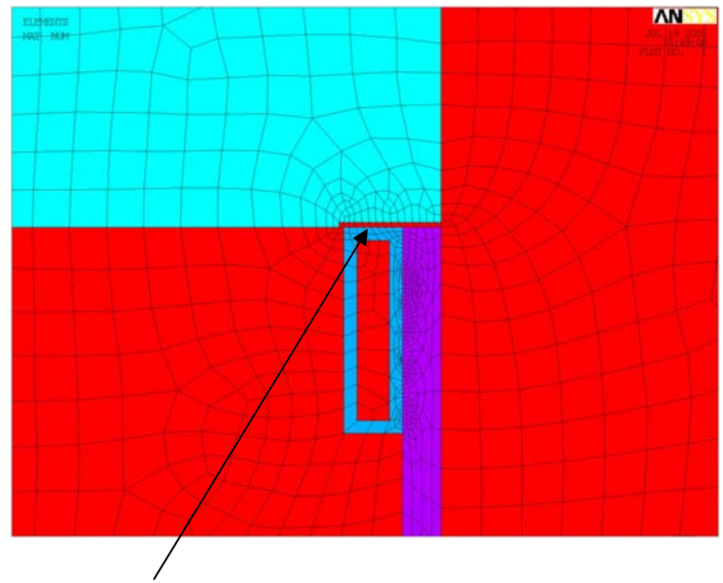
Thin septum global description IV



Thin septum. Magnetic model



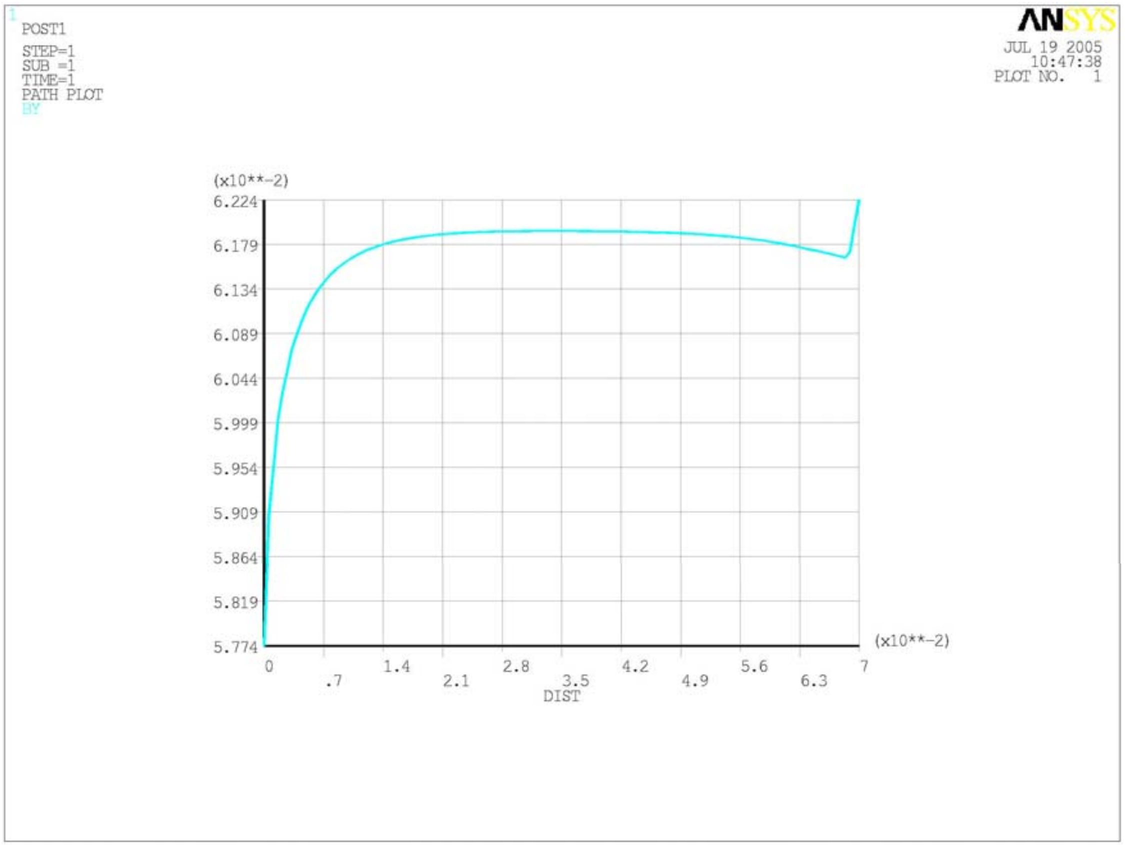
A 2D magnetic model of the septum has been developed in Ansys in order to verify the main characteristics of the cross section



Shape modified after TDR

A finer mesh is located near the septum plate to have a better representation of the field infinite boundary elements are locate on the boundary of the model

Thin septum. Magn. model. Field in the aperture



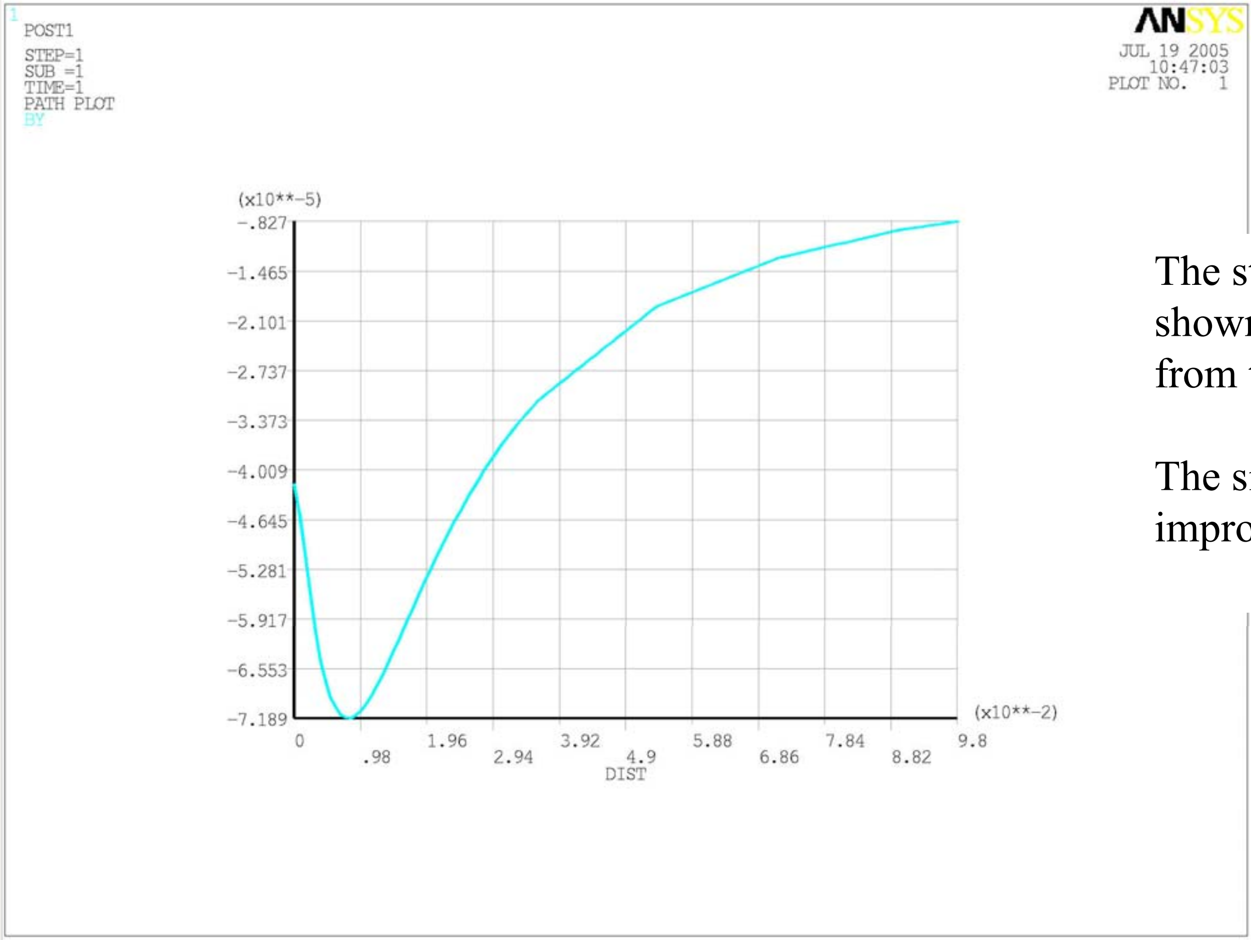
The center of the aperture is at 35 mm.

The field is very homogeneus into the nominal value and it is very homogeneous from about 10 mm to the return conductor (placed at a negative value of the abscissa) up to almost the septum plate

Data at 1975 A

Stored magnetic energy	4.5 J/m
Inductance	1.85 µH
Magnetic pressure	1550 Pa
Lorentz force	60.2 N/m

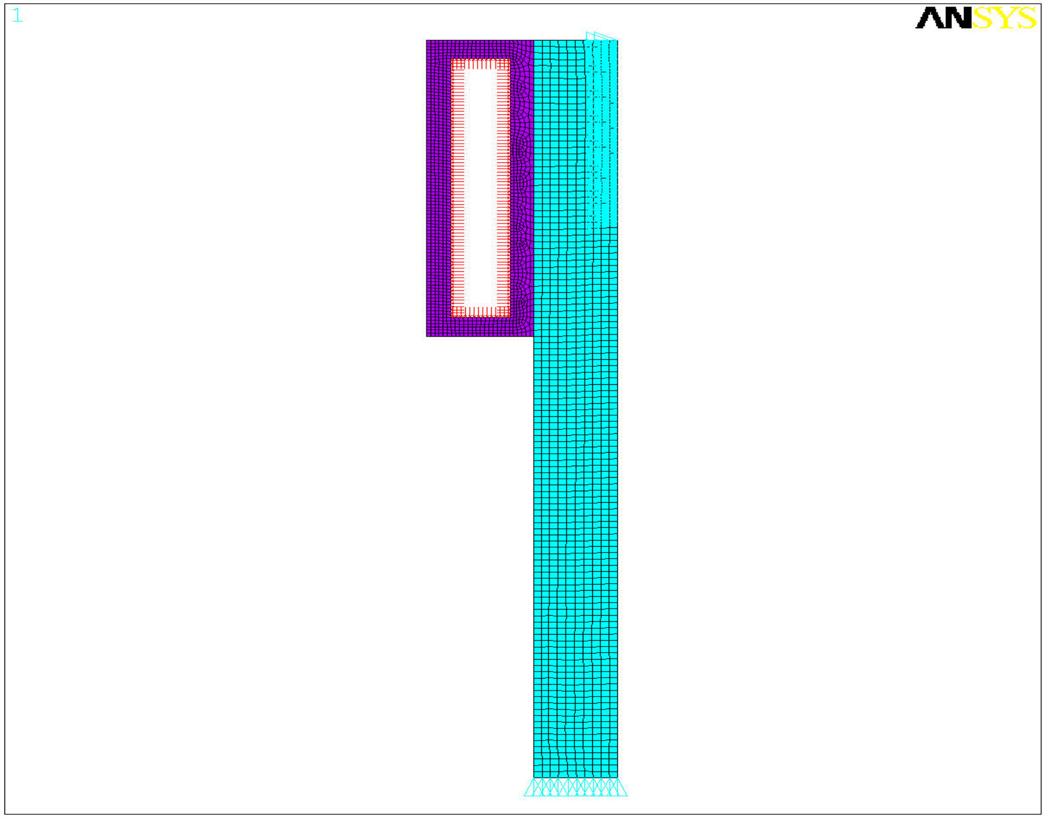
Thin septum. Magnetic model. Stray field



The stray field in the midplane is shown The distance if measured from the septum plate

The situation is VERY much improved since the TDR

Thin septum. Mechanical model



A 2D mechanical model has been developed and tested under two load cases:

1. With the Lorentz forces taken by the septum plate

2. Under the 12 bar test pressure applied on the inside of the cooling pipe.

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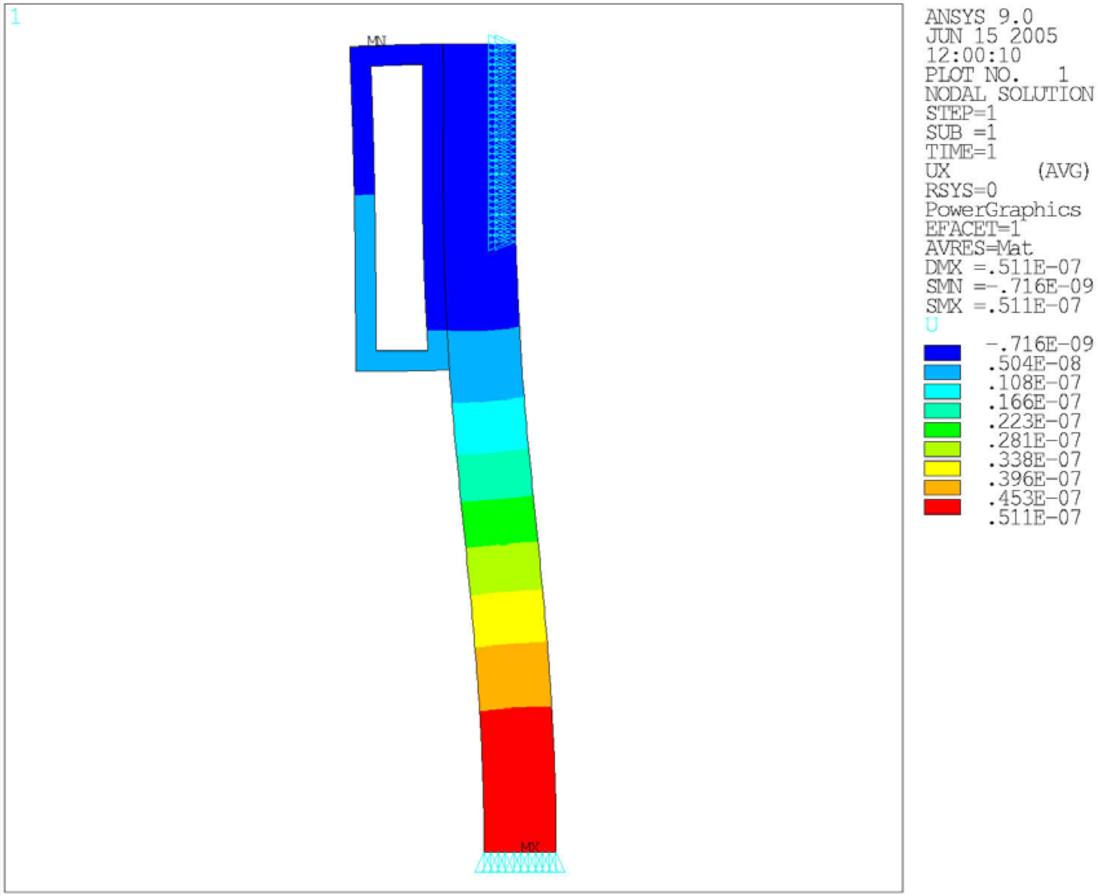
Thin septum. Mechanical model. Lorentz forces



The displacement due to the Lorentz forces is smaller than 1 μm.

The Von Mises stress is smaller than 1MPa

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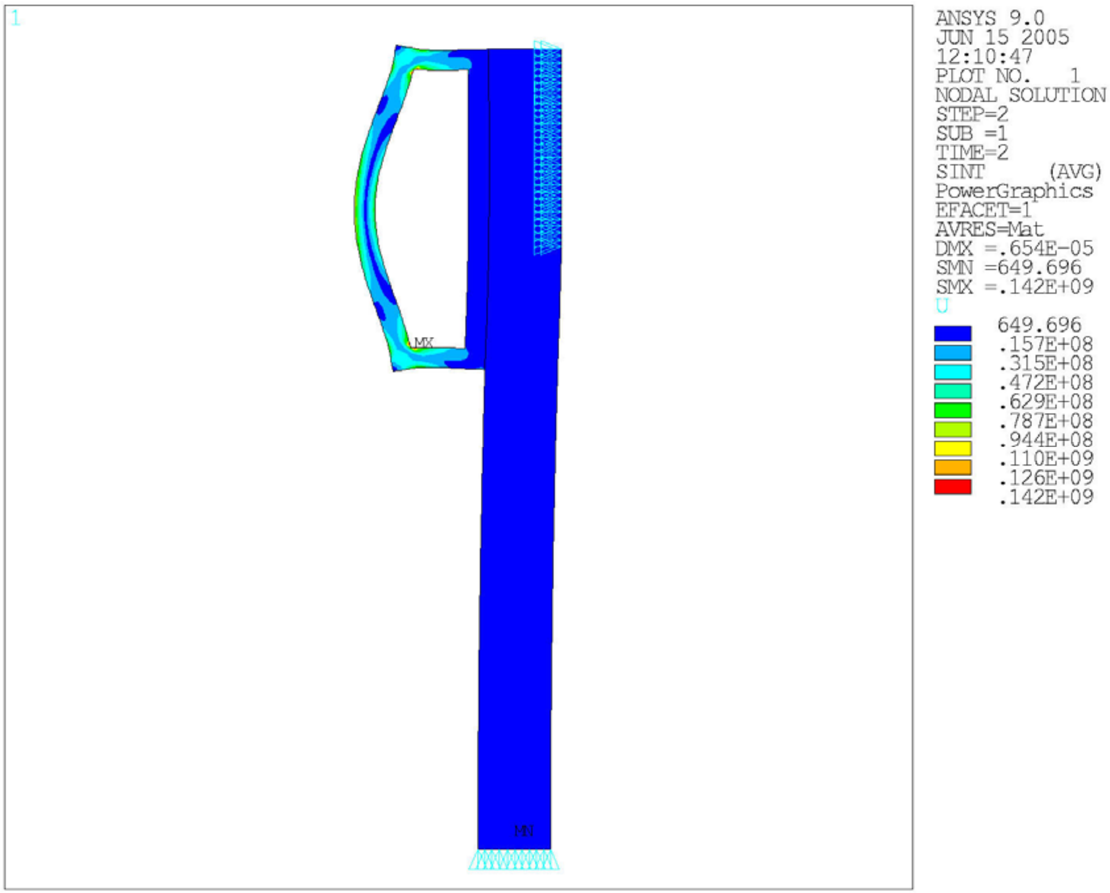
Thin septum. Mechanical model. Internal pressure



The thickness of the cooling pipe is limited by the internal pressure.

0.5 mm is the minimum required by the present height of the cooling pipe

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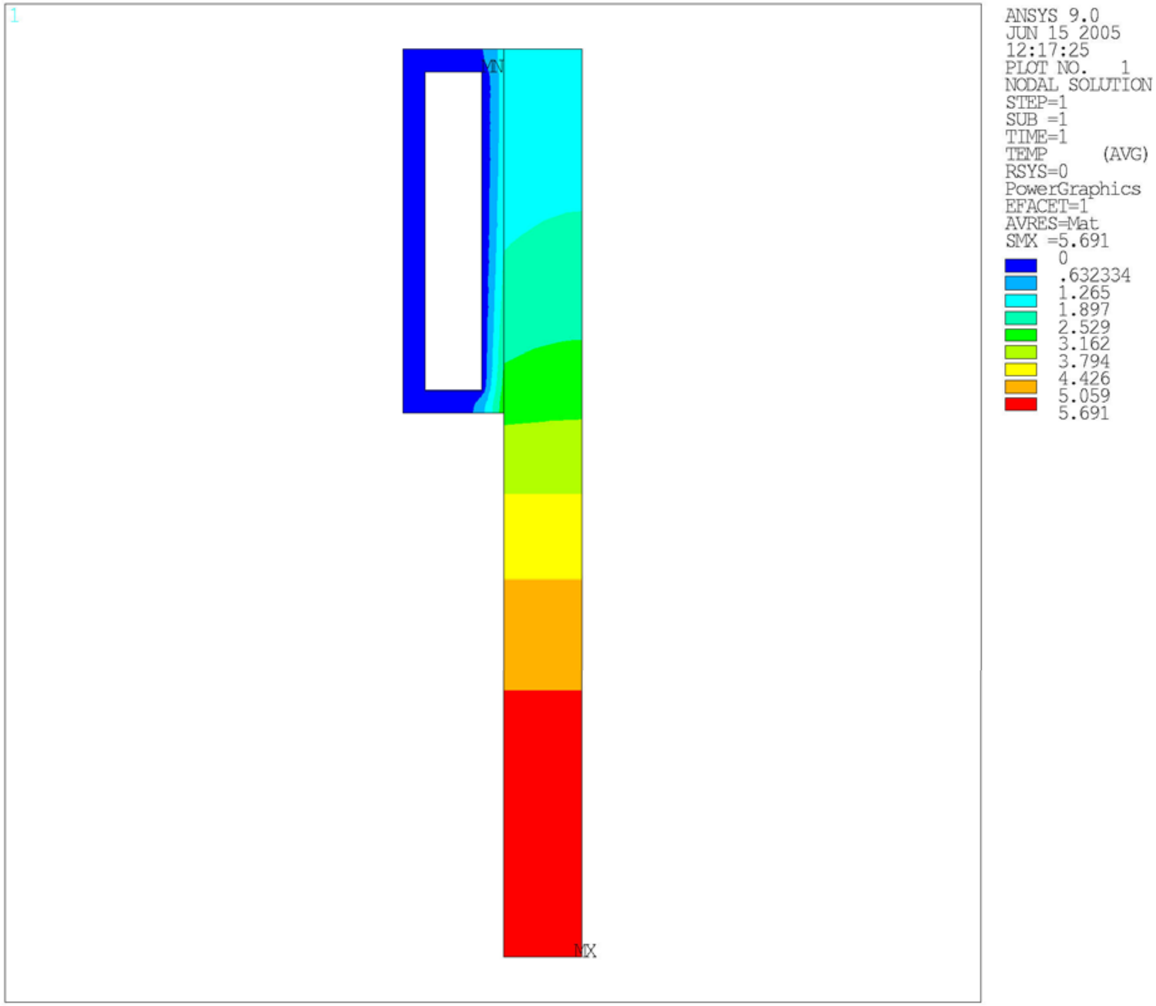
Thin septum. Thermal model



Due to the large septum plate, it is important to know which temperature gradient is established along the conductor

The conductor hot-spot is almost 6 K hotter than the cooling water

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Thin septum. Cooling analysis

Section	N	Section	Hid. Diam	Length	Speed	Reynolds	DP	Resist.	Power
Feed pipe	2	7.85E-05	1.00E-02	0.450	2.43E-01	2.43E+03	6.65E+01	5.07E-05	1.98E+02
Capillary	2	8.90E-006	0.0022	0.900	2.15E+00	4.62E+03	4.83E+04	2.25E-04	8.78E+02
Back cond.	4	7.07E-06	3.00E-03	0.900	1.35E+00	4.05E+03	1.37E+04	4.60E-05	1.79E+02
Return pipe	1	1.13E-04	0.012	0.450	3.38E-01	4.05E+03	1.07E+02	5.80E-05	2.26E+02
Total							**6.21E+04**	**3.80E-04**	**1.48E+03**

The pressure drop is calculated using Moody's chart and the Darcy equation.

The table above, is a summary of the calculations performed in the different sections of the septum. For a mass flow of 2.3 l/min, the pressure drop is 0.62 bar and the dissipated power about 1.5 kW, corresponding to a water temperature increase of 10 K or less.

Thick septum.

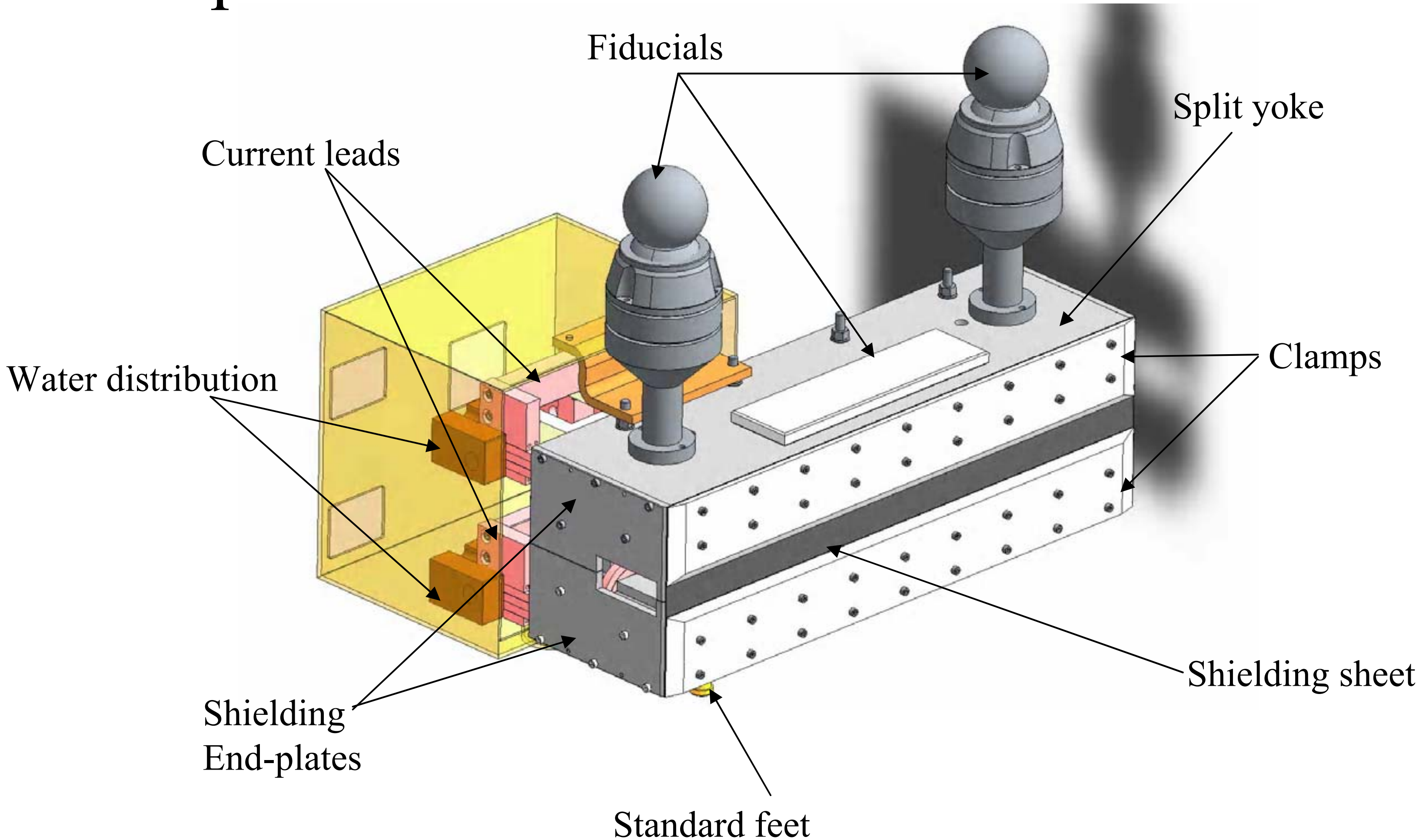
The thick septum design is based on a 4 turn magnet divided in two coils.
The 4 turns are in 4 independent water circuits

An horizontally split yoke, allows for the insertion of the magnet around the vacuum chamber.

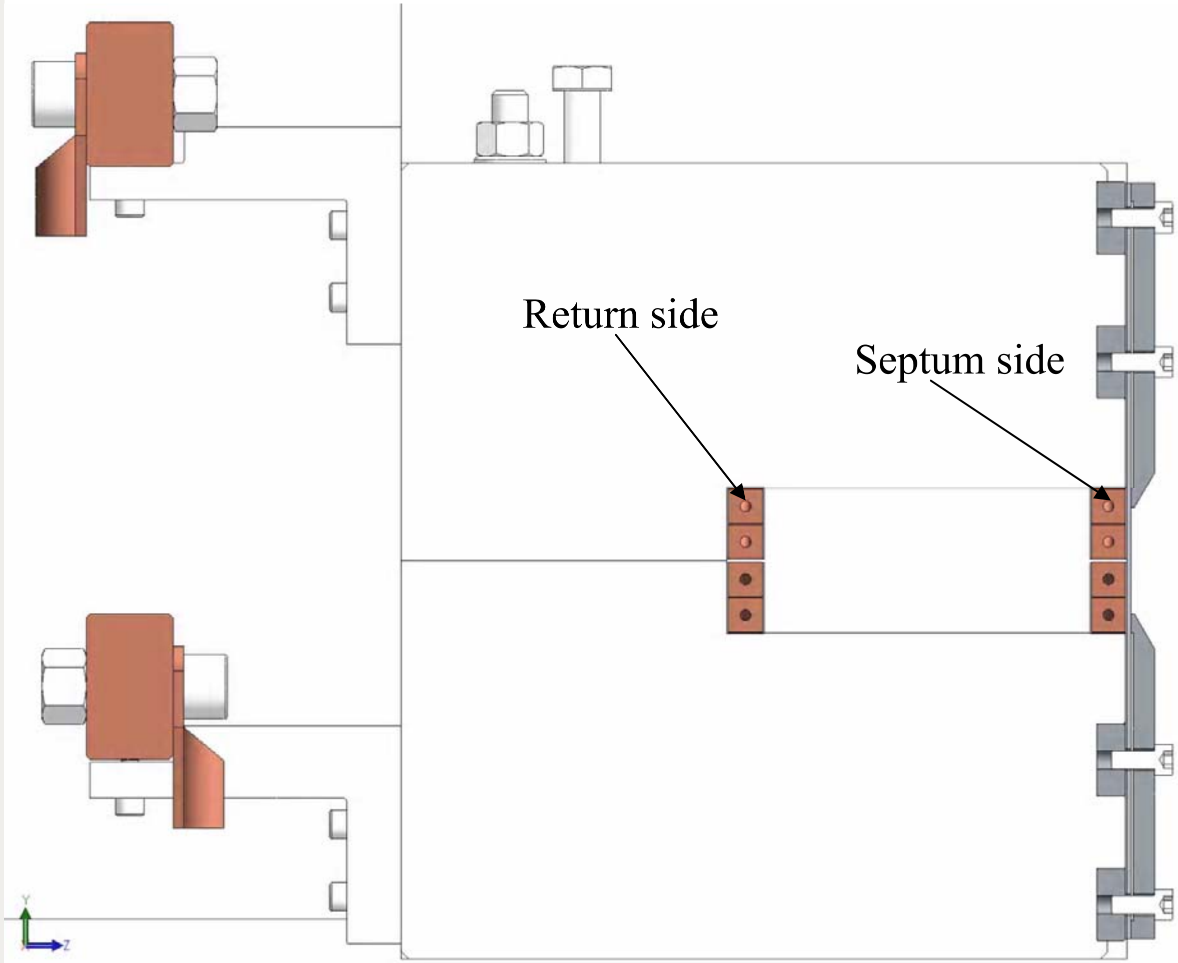
The circulating beam is shielded from the stray field by a 1 mm mu-metal sheet

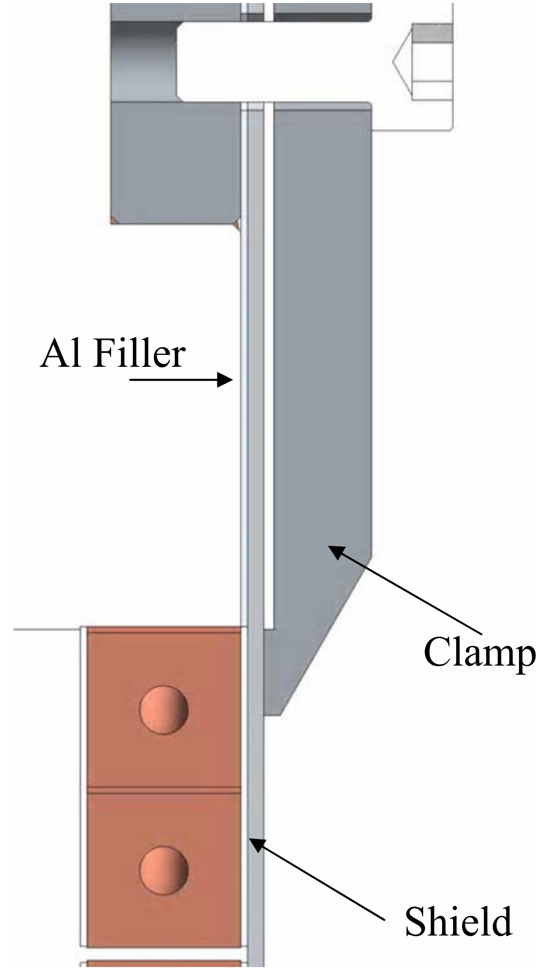
Iron end-plates shied the stray field in the ends and control the magnetic length

Thick septum. General view 1



Thick septum. General view II





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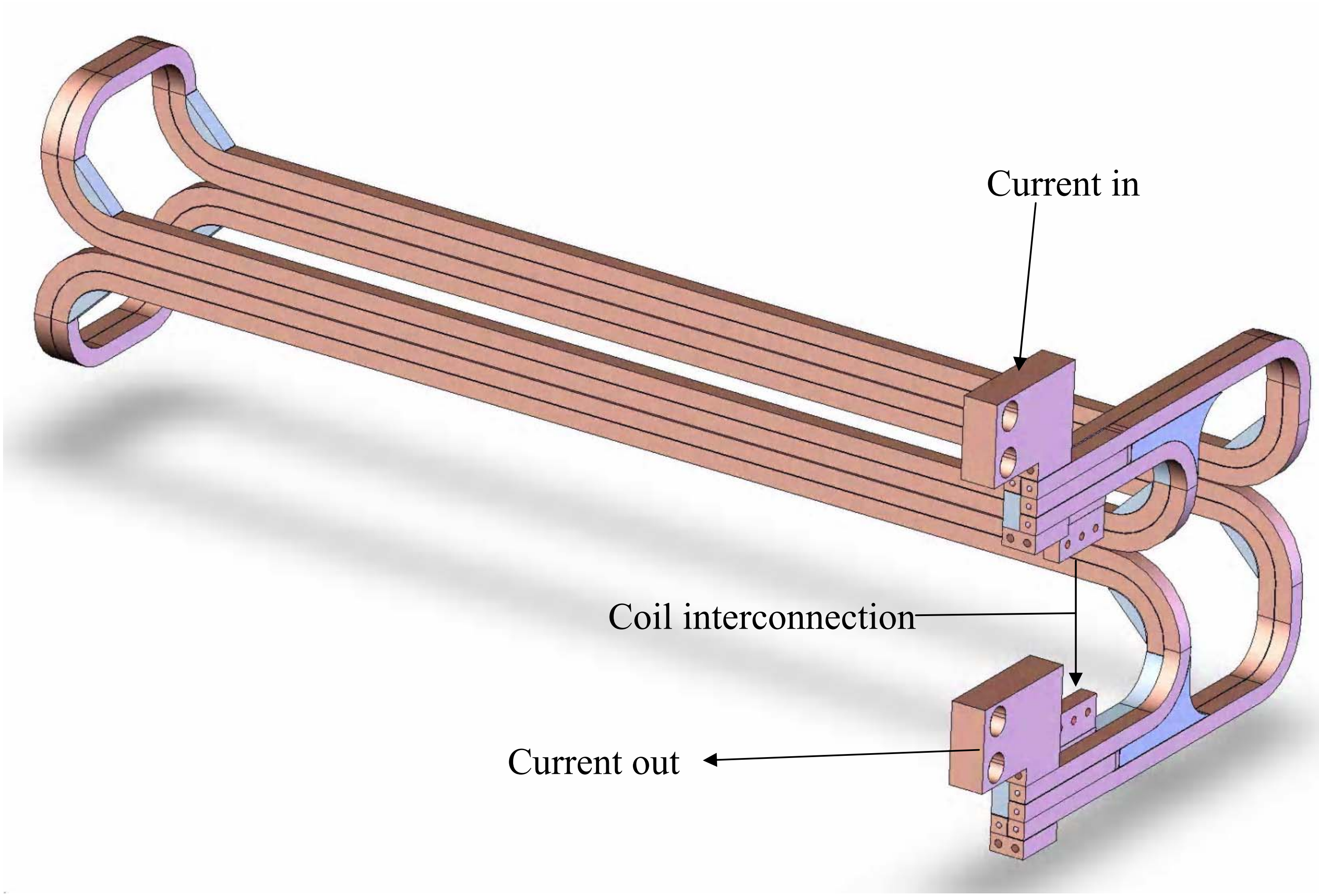
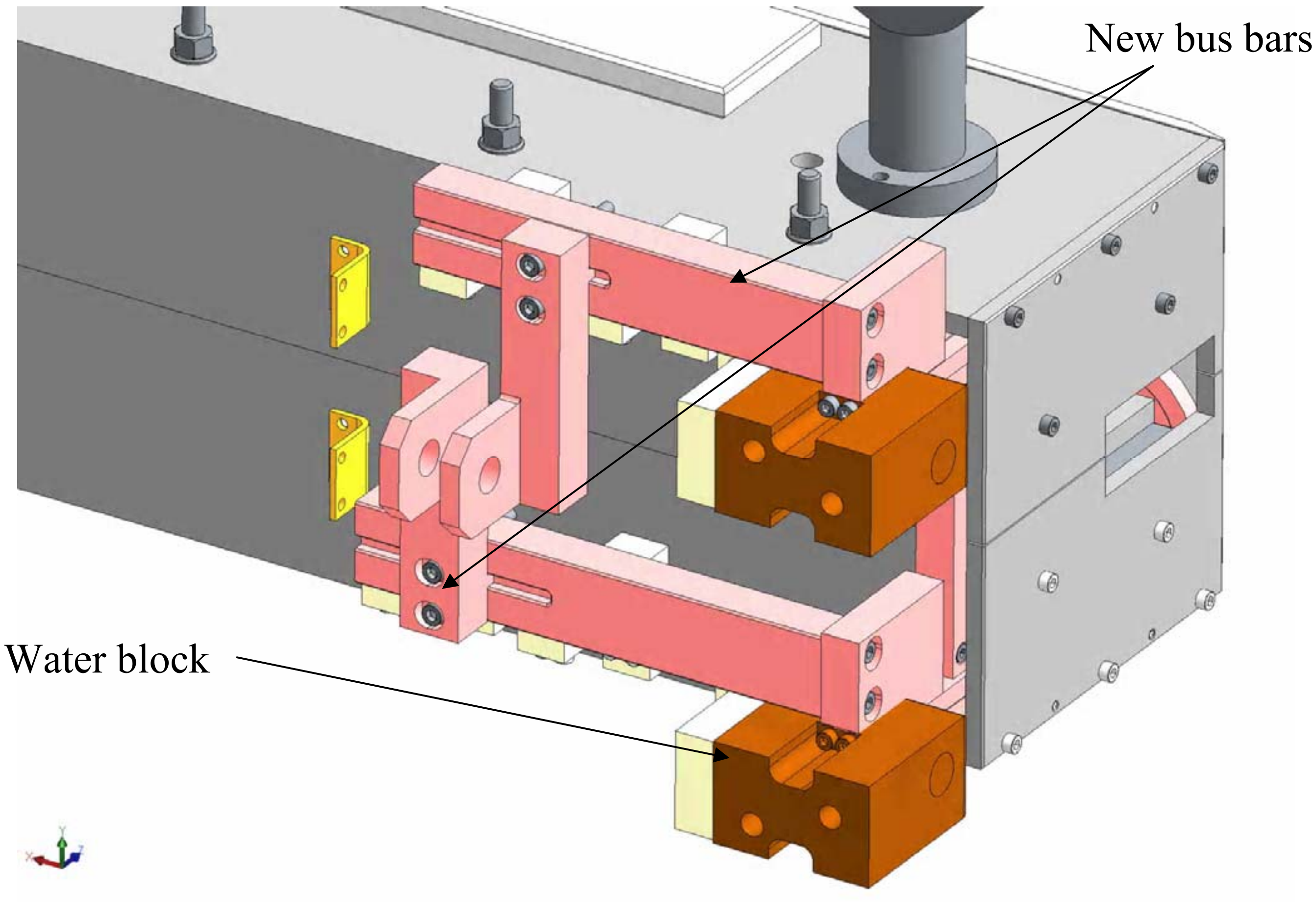
Thick septum. Coils



Thick septum. Water feed and bus bars

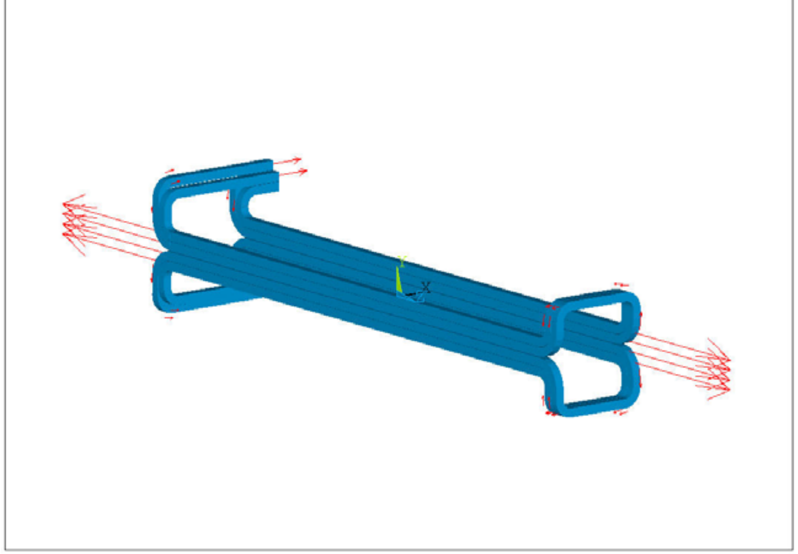


Thick septum. Magnetic model

A 3d model of the thick septum is used to investigate its properties.

The model is refined in the end regions as most of the 3D effects happen there.

Coils



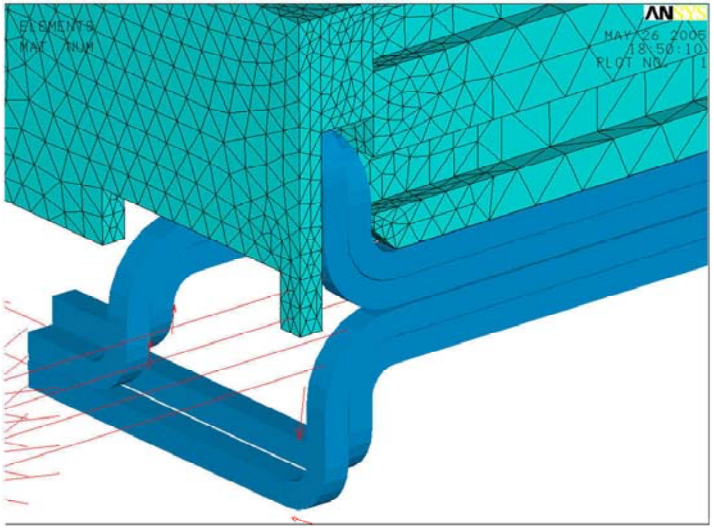
Full model (no air)

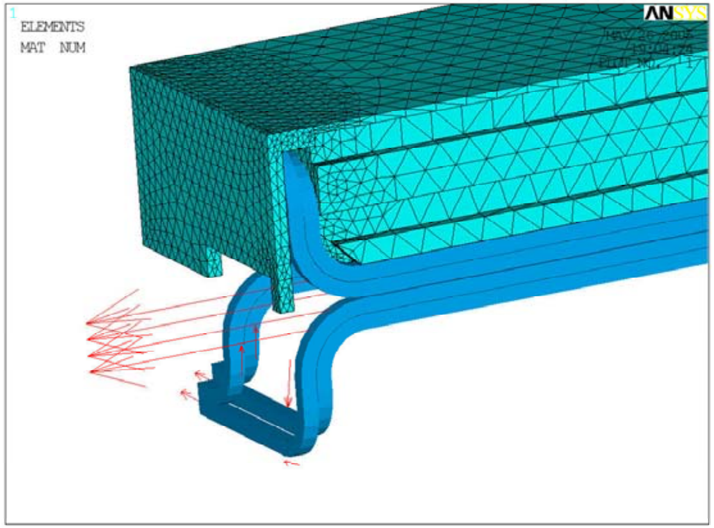
Shielding sheet taken out

Thick septum. Magnetic model

Two different designs have been compared

1. The first one uses a very tight bending of the conductor, 1.5 times the height of the conductor
2. The second one uses 3 times the height of the conductor as the bending radius





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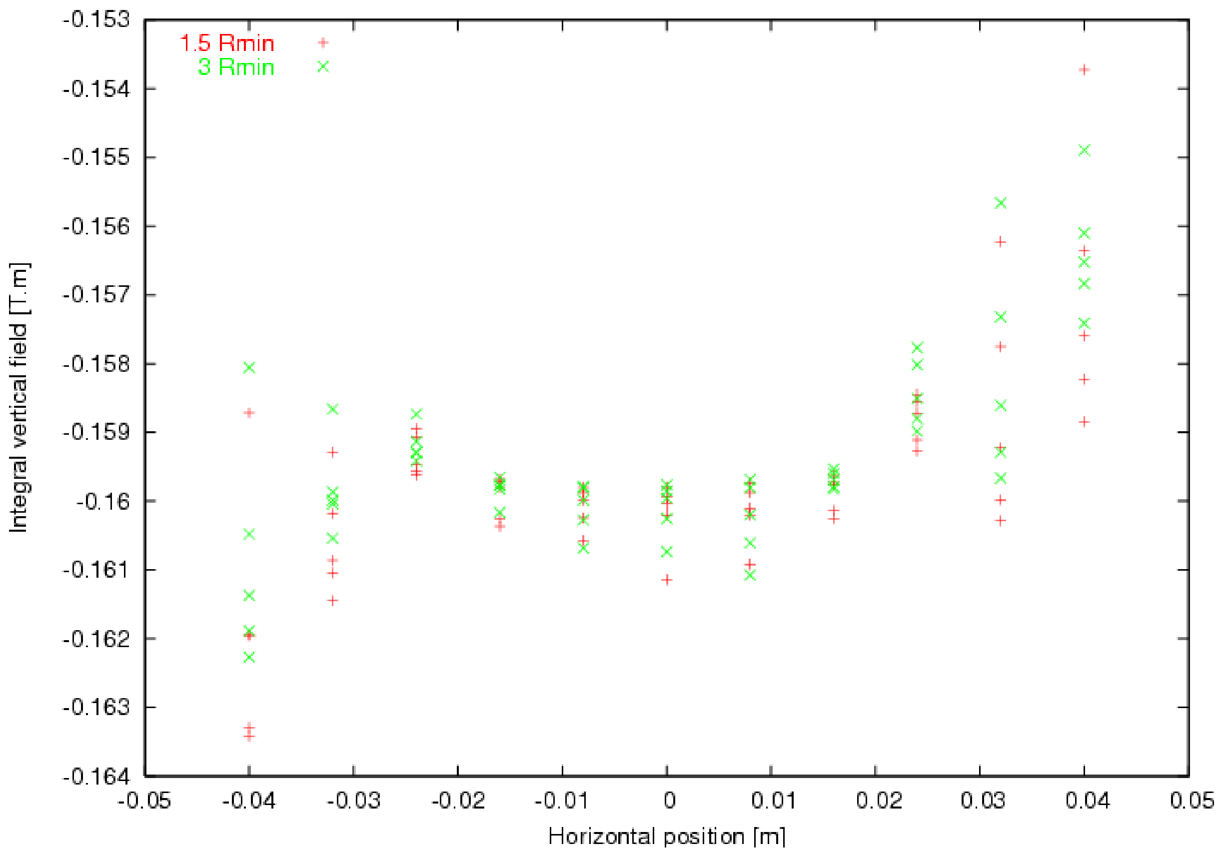
Thick septum. Extracted beam field

The integral field in the central trajectory is 0.1597 T.m for the case in which 3 times the conductor width is used, and 0.1598 T.m

Both are similar from the homogeneity point of view. The large radius have been retained

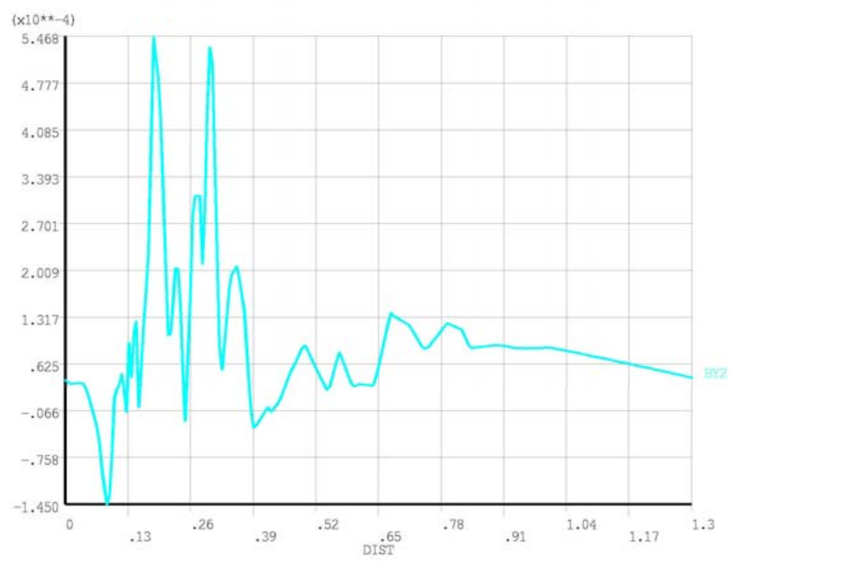


Thick septum. Stray field

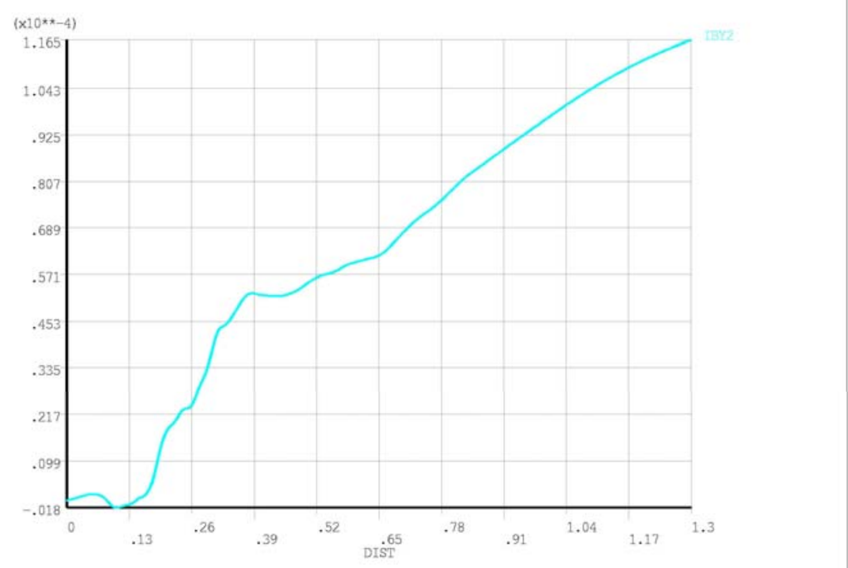
The field in the region of the circulating beam is of the order if 1 G.
The FEM model cannot calculate to this level of accuracy.

In any case, the field screening is very efficient.

Stray field



Integral Stray field



Thick septum. Thermo hydraulic analysis

Per turn: $$R=\rho\frac{l}{A}=0.41\Omega$$ the power dissipated per turn will be **1.60 kW**

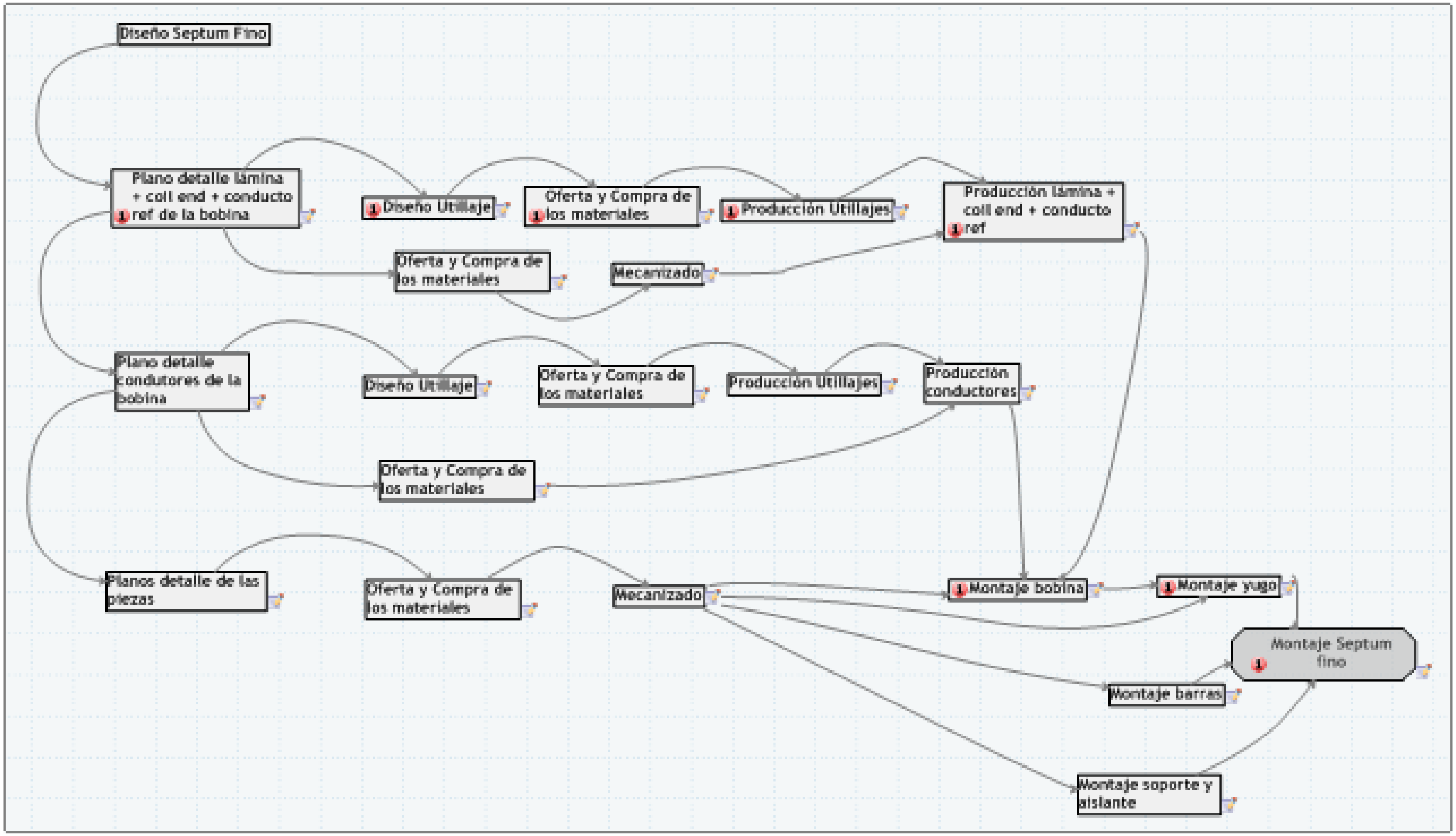
We have calculated that for a flow mass of **2.76 kg/min** per turn, the water speed is **6.50 m/s,** corresponding to a Reynolds number of 19500

The pressure drop, from the darcy equation will be:

$$\Delta P=f\frac{L}{D}\rho\frac{v^2}{2}=510^5 Pa$$

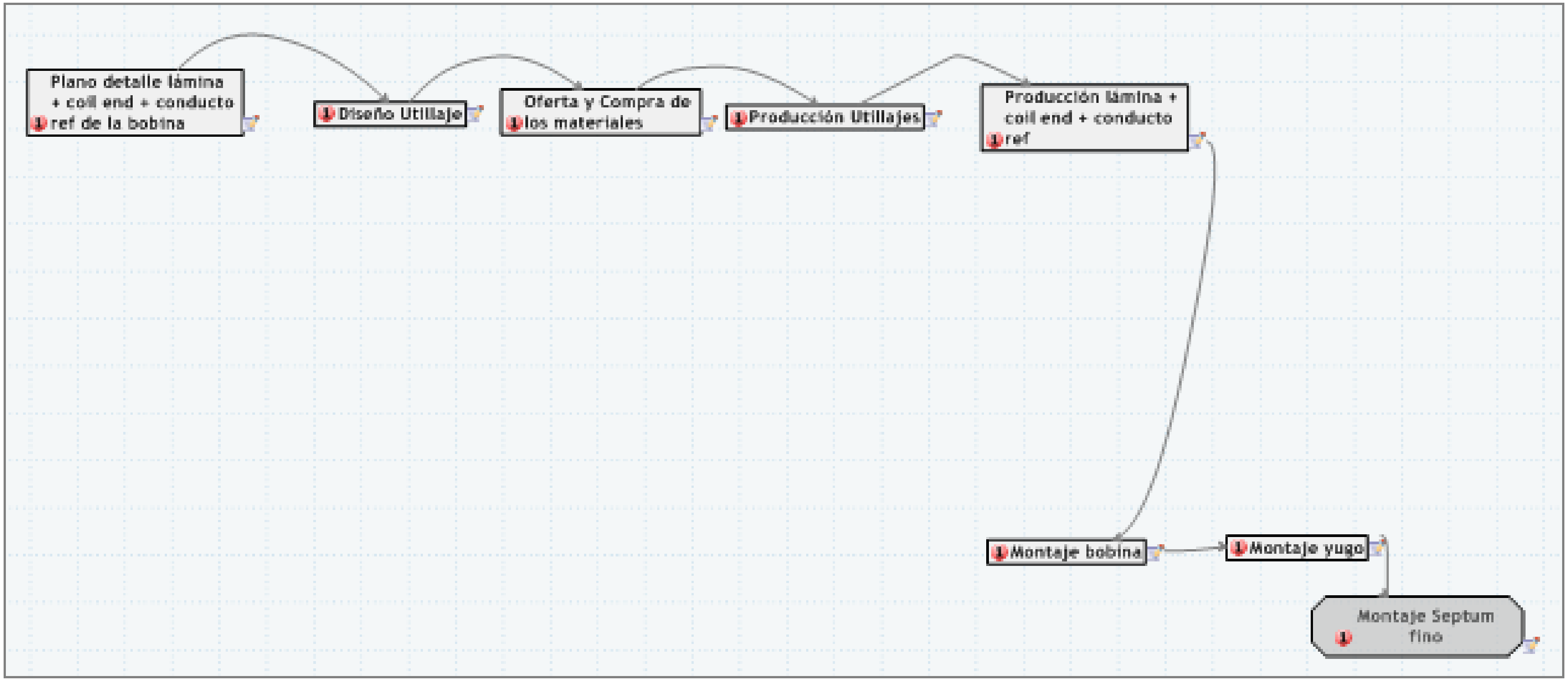
A **5 bar** pressure drop should be well matched to the facility available pressure. The corresponding water temperature increase is **8.4 K.**

Thin septum fabrication steps I



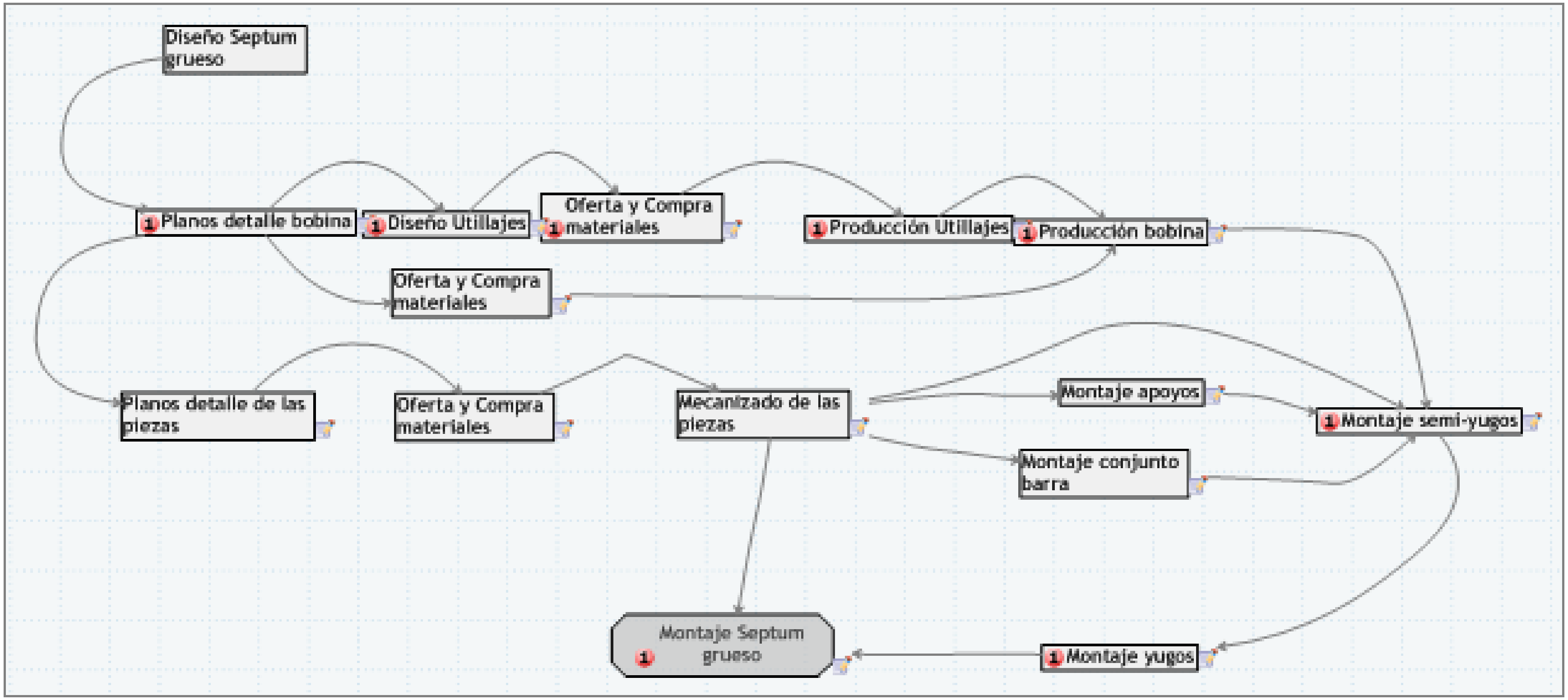
Thin septum fabrication steps II

The **critical path** goes through the coil brazing tooling



Thick septum fabrication steps

The **critical path** goes through the coil impregnation mould



Conclusions

We have completed the following steps:

- Conceptual design of both type of septa
- Solid modelling of the magnets
- Manufacturing drawing of the components
- Manufacturing drawings of the tooling
- Iron and copper are being supplied to Ciemat
- We have offers for the manufacturing of the components, the components should be made for the end of the year