High Current Density Septa for DAΦNE Accumulator and Storage Rings

M. Modena, H. Hsieh and C. Sanelli
INFN Laboratori Nazionali di Frascati
C.P. 13 - 00044 Frascati (Roma) - Italy

Abstract

An injection/extraction magnetic system composed of two septa is being designed for both the accumulator and the storage rings of the DAΦNE project. A multi-turn DC high current density septum provides the principal bend of 0.593 radians it is followed by a 0.038 radians capability thin septum which is located nearer the machine. This septum is of high current density and edge cooled type. This paper describes the magnetic and thermal results by FEM. Mechanical design of the septa is also presented.

1. INTRODUCTION

A 510 MEV electron positron colliding facility [1], known as DAΦNE, is currently under design and construction at INFN's Frascati National Laboratory. The project consists of two storage rings and one energy injector system. Electrons and positrons will be injected into the DC accumulator alternatively from Linac at a frequency of 50 Hz. The storage rings will only have injection frequency of once per second. Figure 1 depicts the physical layout of the system. Keeping long term operational reliability in mind, we have elected to build DC septa instead of rapid pulsing ones in spite of all the problems associated with high current density devices. Both septa are placed outside of machine vacuum chamber, so that the possibility of water leak inside a ultra high vacuum environment can be avoided. The penalty of this approach is thinner septum therefore higher current density.

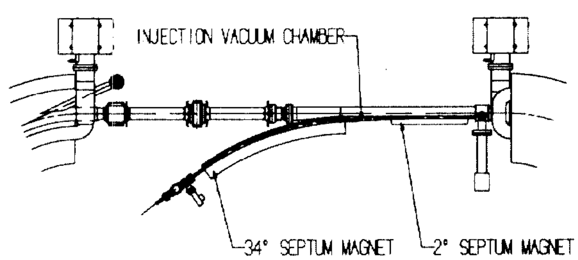

Figure 1. Injection/extraction Septum System

2. EDGE COOLED DC SEPTUM

2.1. Configuration

Figure 2 shows the cross section of the thin septum. The allowable maximum septum thickness set by machine physics group is in the order of 4 mm, it of course includes the thickness of two vacuum chambers, this reduces the current carrying conductor to 1.5 mm thick. The resulting current density is in the order of 60 ampere per square mm. There are two thin wall, rectangular tubings either brazed or electroformed to form an intimate contact with conductor for proper heat transfer, these tubings will be Inconel alloy or stainless steel 304 L to avoid excessive current sharing with the conductor. The back coil is of conventional copper hollow conductor.

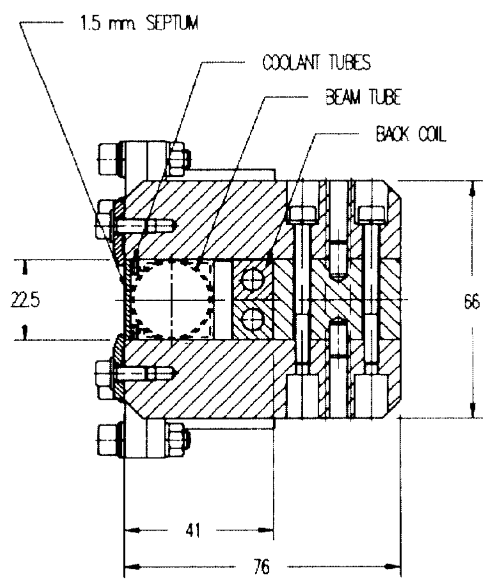

Figure 2. Thin Septum Section

All the electrical insulation will be provided with 130 μm thick pressure sensitive Kapton tape. The additional function of the Kapton tape, due to its extreme low thermal conductivity, is to insulate thermally the beam chamber from high temperature septum, this will prevent the thermal outgassing of the stainless steel septum beam tube so near to the machine that it is considered as part of machine vacuum. The iron yoke is of low carbon steel solid type, it is detachable so that the septum can be installed or removed from its location with ease. Table I shows some of the more relevant parameters of this septum.

Table I
Thin Septum Parameter List

Field	0.104	T
Bend angle	38	mrad
Gap height	22.5	mm
Magnetic length	623	mm
Septum conducting area	33.75	mm^2
Current	2125	A
Current density	63	A/mm^2
Resistance	0.33	mΩ
Power	1.49	kW
Voltage	0.7	V
Number of water circuit	1	
Water flow rate	0.1	L/s
Water pressure drop	3	Atm
Water temperature rise	5	°C

2.2 Analysis Results

The thermal loading of the thin septum is rather severe due to high current density and edge cooled feature. Heat transfer has been performed by using ANSYS code, with initial water temperature of 30 °C, the maximum temperature along the median plane is in the order 51 °C, there are negligible thermal gradient across the tube wall. Assuming tubings remain rigid, the maximum thermal compressive stress in the copper will be in the order of 440 kg/cm^2, which is below endurance limit of the copper. Magnetic calculation has been carried out with POISSON code, taking into account the real current distribution within the septum and coolant tubes.

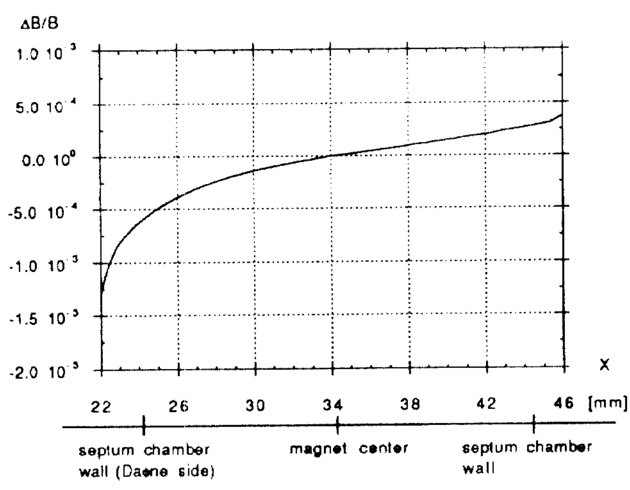

Figure 3. Thin Septum Field Quality

Figure 3 shows the field quality along the x-direction, the uniformity is in the order of $\pm 5\ 10^{-4}$ within the beam tube region. The fringe field outside the gap is shown in Figure 4, they are 1.2 Gausses at 2 mm from machine vacuum chamber wall and 0.75 Gausses at the injection straight section, the gradient is in the order of 0.25 G/cm.

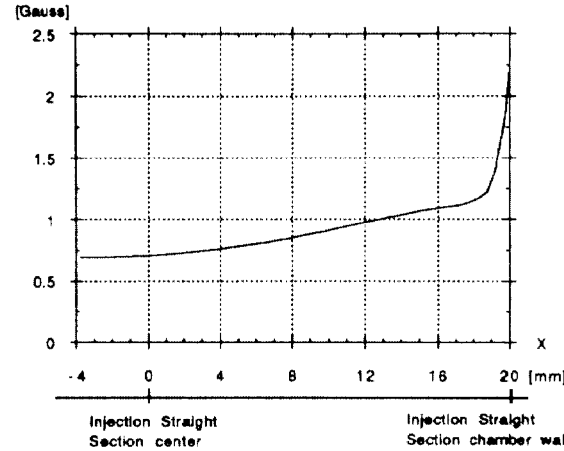

Figure 4. Thin Septum Fringe Field

3. The Multiturn Curved Septum

3.1 Configuration

Figure 5 shows the cross section of multiturn curved septum. It is of conventional hollow conductor coils and solid low carbon steel yoke. The coil package consists of eight turns of hollow conductor, 6 mm x 6 mm with 3.8 mm coolant hole diameter. The coil insulation will be either with kapton tape or conventional fiber glass tape and impregnated with epoxy resin system. The magnet yoke assembly is also of detachable type for the ease installation and removable of this magnet in situ.

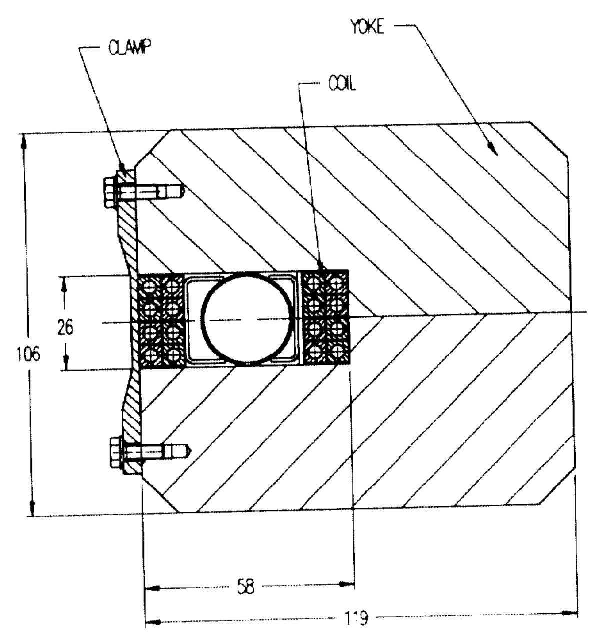

Figure 5. Curved Septum Section

3.2 Analysis Results

The current density of this magnet is in the order of 90 amperes per sq. mm. The power consumption is 68 kW, therefore each turn has to be cooled individually in order to have reasonable water pressure drop. The operating mean temperature of the coil package will be in the order of 50 °C, this may necessitate the cooling of magnet yoke in order to keep the beam chamber at lower temperature. Thermal analysis had been done by classical method and later on checked with ANSYS code. Table II is the parameter list of this magnet.

Table II
Curved Septum Parameter List

Field	0.818	T
Bend angle	593	mrad
Gap height	26	mm
Magnetic length	1233	mm
Ampere turns	17000	
Conductor dimentions	6 x 6	mm^2
Cooling hole dia.	3.8	mm
Conductor area	23.8	mm^2
Current	2125	A
Current density	89.3	A/mm^2
Resistance	15.1	mΩ
Power	68	kW
Voltage	32	V
Number of water circuit	8	
H_2O Rate per magnet	0.653	L/s
H_2O Δpressure/circuit	5.3	Ate
Water temperature rise	33	°C

The magnetic calculation has been carried out by using POISSON code. Figures 6 and 7 depict the field quality inside the magnet gap and fringe field outside the septum. The field quality is well within ± 5 10^{-4} range. The fringe field outside the septum is very low. The perturbation due to the end nearer the machine will be studied and shielded if necessary.

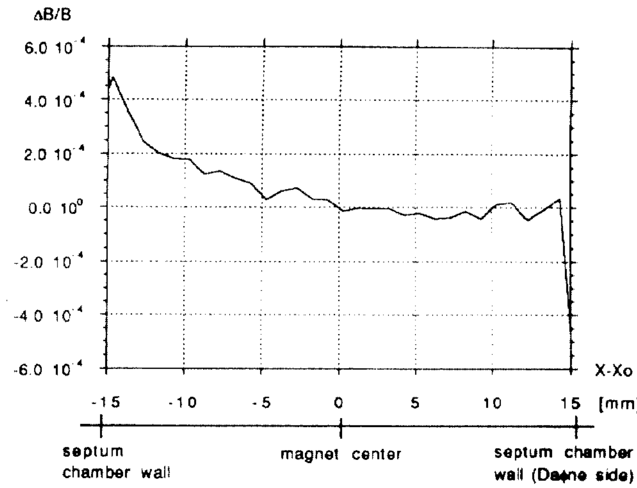

Figure 6. Curved Septum Field Quality

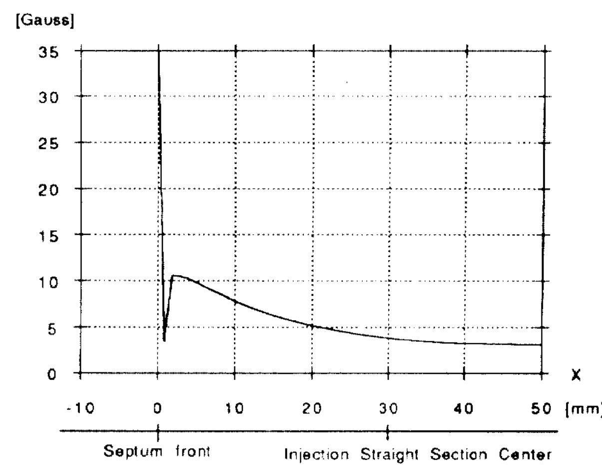

Figure 7. Curved Septum Fringe Field

4. CONCLUSION

We have determined the approach of septa design is feasible and the magnetic performances will satisfy the requirement set by the machine physics group. The mechanical design of the septa is under way. The prototypes will be built to verify the validity of computation. The fringe field will be carefully studied, magnetic shield will be implemented if necessary.

5. REFERENCES

[1] The DAΦNE project team, "DAΦNE status report", this Conference.