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CERN - PS DIVISION

PS/ CA/ Note 98-11

MAGNETIC MEASUREMENTS OF THE MODIFIED SEPTUM SMH16 (LEAD ION)

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1. Introduction

During the start up of the PS accelerator in March 1998, a noise was noticed in the vacuum chamber of bending section 15 when the pole face windings of the PS main dipoles were pulsed. After venting the sector to atmospheric pressure, bits of what seemed septum laminations were found in this vacuum chamber next to septum 16. Since no apparent damage to the septum magnet was visible, it was decided not to install immediately its spare magnet. The magnet had already been installed and functioned properly for four years. However to be on the safe side, it was decided to reinforce the spare magnet at the yoke extremities, as is standard technology for the more recently constructed pulsed septa magnets. This note describes the modifications made by D. Rosset affecting the magnetic circuit, followed by the results of the magnetic measurements.

2. Modifications affecting the magnetic circuit

The modification made to the yoke consisted of replacing the last 4 laminations at the end of both yoke extremities by a 1.5 mm thick stainless steel lamination to support the steel laminations in the longitudinal direction. The stainless steel lamination being non magnetic implies that the magnetic field will not induce a force on this lamination while its increased thickness will make it more rigid hence a support for the neighboring steel laminations in the longitudinal direction. To provide additional support, a Vespel clamping plate has been put in between the stainless steel lamination and the end plate of the magnet. In figure 1 below the old situation (1) and the modified situation are shown (2).

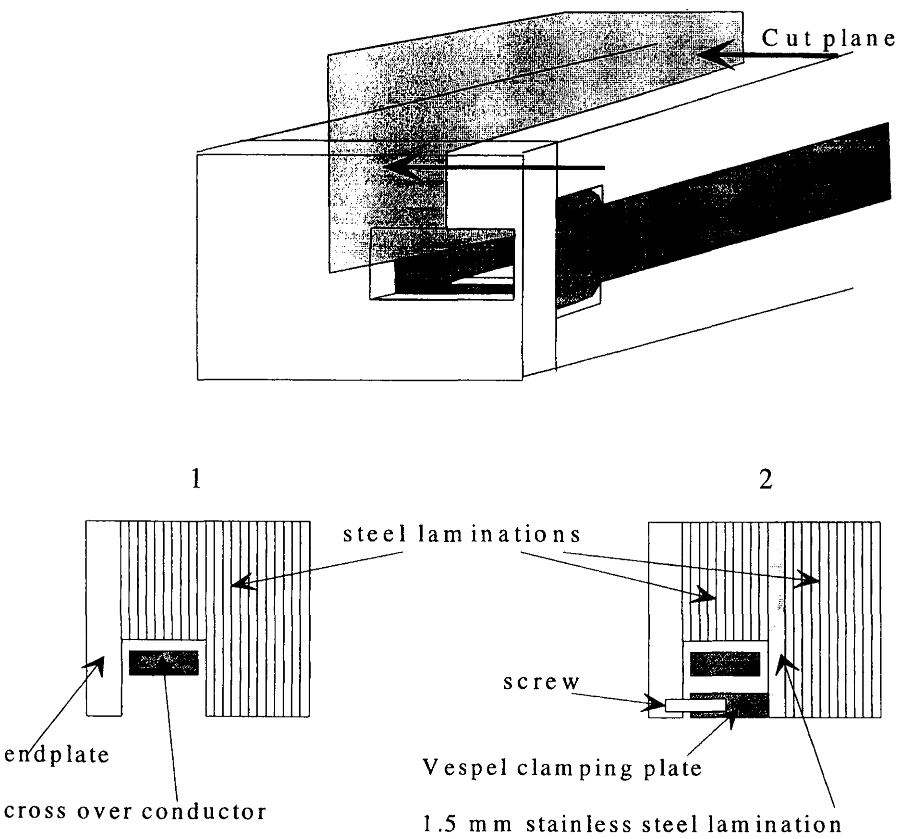


Figure 1: Yoke modification. The old (1) and the modified situation (2).

Since the total length of the magnet hasn't changed, the length of the magnetic yoke is reduced by twice the thickness of the stainless steel lamination. Eddy currents induced in the screw to fix the insulating Vespel shim, will have a small local influence on the field quality at the ends of the magnet. However this effect will be neglected.

3. Measurements on SMH 16.2

Before the magnet was installed in the PS ring in January 1994, the magnetic performance was tested. When referring to measurements done before modification in this note, this refers to these initial measurements as described in Note PS/PA 94-27.

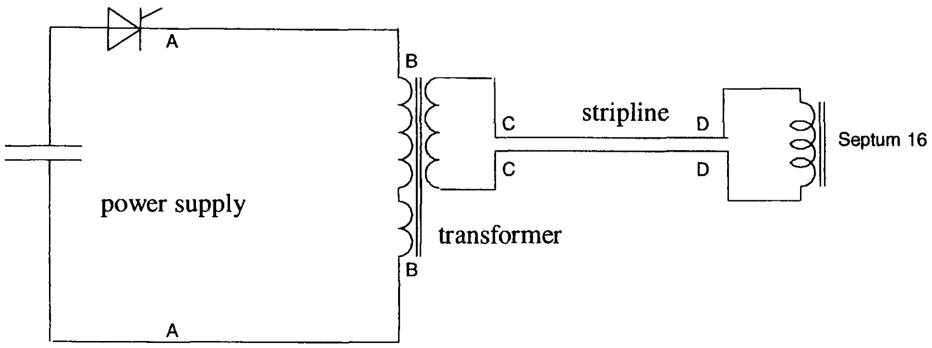


Figure 2: The circuit diagram

In figure 2 the circuit diagram is shown. The circuit specifications were:

Capacitance	2 mF
Transformer	12 : 1

The measuring equipment used was:

Impedance meter	H.P. Model
Current Transformer	Pearson Model 1423 (1 V/kA)
Digitiser	Tektronixs 7612D
Data handling	PC 486 running labview
Scope (current measurements)	H.P. Model 54601 A

Septum 16 consists of two separate magnets in series which have an angle of 20 mrad with each other. This is illustrated in figure 3.

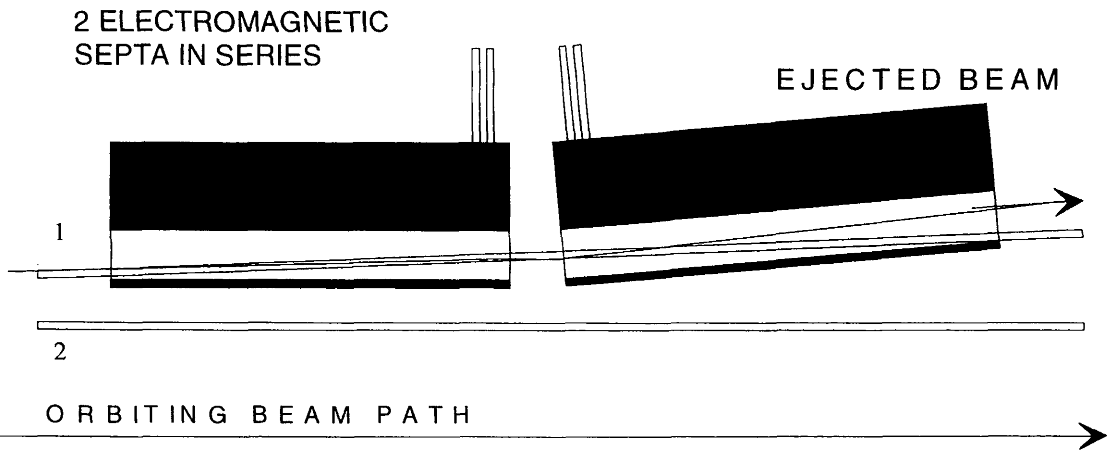


Figure 3: Layout of SMH16, and positions where measurements were taken: Integrated field of the magnet in the gap (coil 1), fringe field measurements parallel to upstream magnet (coil 2)

3.1 Inductance measurements

Using the H.P. impedance meter the values of resistance and inductance of magnet 16.2 and stripline A-D and the stripline A-D only were measured. This way the inductance as seen by the primary of the power supply can be determined. These measurements were taken at 2 frequencies. In table 1 the results are reproduced and compared to the values measured in 1994 before the modification.

Table 1 : inductance of magnets at different frequencies taken in 1994 and in 1998 after modification

	SMH 16.2 (before mod.)		**SMH 16.2 (after mod.)**	
Frequency	1 kHz	120Hz	1 kHz	120Hz
Magnet inductance	**5.32** μH	**5.53** μH	**5.11** μH	**5.28** μH

The same impedance meter was used in 1994 and now, but the transformer changed and another stripline was used. The difference is unexpected, and is suspected to be due to a measurement error. When using a Fluke Philips PM 6309 RCL meter directly on the magnet connections, a value of 5.41 μH was measured at 1 kHz. But no value could be obtained at a lower frequency. This demonstrates however that the measurement equipment used is not the most adapted, hence the error margin.

3.2 Magnetic measurements

Using a power supply based on the circuit as shown in figure 2, with a pulse repetition rate of approximately 4.5 seconds, a series of measurements were recorded in order to determine the magnetic field in the gap and the fringe field. The field in the gap was measured to determine the actual punctual values as well as the integrated field (Bdl) from which we can calculate the equivalent magnetic length of the magnet.

The measurements we taken with the Tektronics digitizer and transferred to a PC running a Labview application as described in Cern Note PS/PA/95-13.

In Appendix 1 the results of the measurements are shown. The equivalent length calculated as a result is shown in table 2 as well as the results of the measurements in 1994 before modification. With the new measurement chain (digitizer and pc) the results are more accurate, while there original results from 1994 showed a wide spread. Therefore the expected reduction of approximately 6mm cannot be confirmed, but it can be concluded that the magnetic equivalent length after modification is 2174 ±4 mm.

Table 2: The magnetic equivalent length as measured in 1994 before modification and after modification

Iseptum (kA)	SMH 16.2 before mod. (1994) (m)	SMH 16.2 after mod. (1998)(m)
3.8	**2.10**	**2.178**
14.4	**2.15**	**2.177**
21.8	**2.22**	**2.170**
28.7	**2.19**	**2.172**

The fringe field has been measured and the results are shown in table 3 for as well the measurements before modification (1994) and after modification (1998).This time only the fringe field at 28.7 kA has been measured.

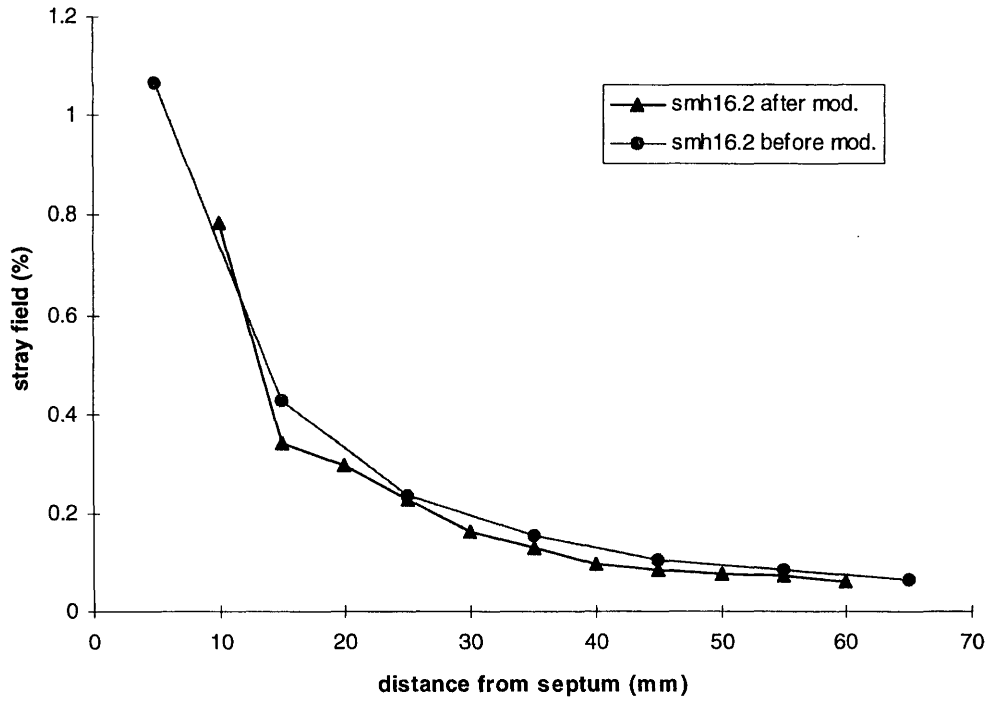


Figure 4: The relative fringe field at 28.7 kA on SMH 16.2 before and after modification.

4. Conclusions

The magnet yoke has been reinforced by replacing four steel laminations by one 1.5 mm thick stainless steel plate. This plate is kept in place by a Vespel clamping plate in the longitudinal direction as well, so fatigue due to end lamination movement will be dramatically reduced.

The inductance measurements show a 2 - 4 % decrease in inductance, which is rather surprising, but this is expected to be due to a measurement error.

The integrated field measurements of the modified magnet have shown that the magnetic length is 2173 mm ± 3 mm, as expected. Since the present measurement system allows to do these measurements far more precisely, it is difficult to compare these results with the results before modification, since they had a large measurement error.

The fringe field next to the septum blade of the magnets is low, lower then 1% of the gap field at 10mm from the septum, and lower then 1/1000 at 50 mm distance from the septum. Even slightly less than before the modification.

Appendix 1. The magnetic measurements on the modified septum 16.2

Inductance measurements

	SMH 16.2 (before mod.)		SMH 16.2 (after mod.)	
Frequency	1 kHz	120Hz	1 kHz	120Hz
Inductance	L(μH)	L(μH)	L(μH)	L(μH)
Short circuit @ D	94.3	104	136	119
No short circuit	861	900	855	897
Magnet inductance	**5.32**	**5.53**	**5.11**	**5.28**

The measurements in the magnet gap

SMH 16.2
15/4/98

coil 1: 0.03693 m2 ; 5 (mm) diam.
coil 2 : 0.10223 m2/m ; 2.5 (m) length

I (kA)	COIL1		COIL2		Leq
	Vdt	B (T)	Vdt	Bdl (T.m)	(m)
3790	5.63E-03	0.1526	3.40E-02	3.32E-01	2.178
14400	2.17E-02	0.5885	1.13E-01	1.281	2.177
21800	3.28E-02	0.8876	1.97E-01	1.926	2.170
28700	4.36E-02	1.181	2.62E-01	2.565	2.172

Fringe field measurements

SMH 16.2
15/4/98

coil 2 : 0.10223 m2/m ; 2.5 length
I : 28.7 kA
Bdl gap : 2.565 T.m

Pos (mm)	Vdt (Vs)	Bdl (T.m)	B.dl (%)
10	2.06E-03	2.02E-02	0.785575
15	8.98E-04	8.79E-03	0.342534
20	7.76E-04	7.59E-03	0.295828
25	6.02E-04	5.89E-03	0.229708
30	4.27E-04	4.18E-03	0.162846
35	3.41E-04	3.34E-03	0.130175
40	2.81E-04	2.53E-03	0.098519
45	2.58E-04	2.20E-03	0.085887
50	2.25E-04	1.98E-03	0.077232
55	1.92E-04	1.88E-03	0.073216
60	1.60E-04	1.57E-03	0.06117

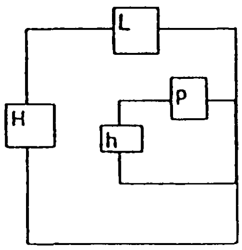
Appendix 2. Magnet characteristics for proton operation at 12 GeV/c, deflection 30 mrad

DONNEES

particules electrons : e protons : p	p	
quant.mouvt : MV Energie cin. : EC	MV	
Quantité de mouvement p =	12	GeV/c
Déflexion requise	30	mrad
Epaisseur du septum	3	mm
Hauteur du Gap	30	mm
Profondeur du Gap	65	mm
Longueur de la culasse	2.142	m
Espace de glissement	0	m
nombre de spires	1	spire
Hauteur de chaque conducteur	30	mm
Largeur de chaque conducteur	4.5	mm
Résistivité du cuivre (1.72E-2	0.0172	mO.mm
module d'Elasticité (12500	12500	daN/mm2
Forme de l'impulsion		
DC , 1/2 sinus : S , trapèze : T	S	
1/2 période de l'impulsion	3.8	ms
Période de récurence (cycle tot.	2.4	s
soit le taux de répétition		
% du conducteur pour refroidissement	4	%
Elévation de température moy.admise	5	oC
ex: AA avec dT =20 Temp.max=60oC		

RESULTATS PROTONS

Masse au repos mo	0.94	Gev/c2
Energie cinétique	11.0968	GeV
Quantité de mouvement	12.0000	Gev/c
beta	0.9969	
gamma	12.8051	
beta*gamma	12.7660	
Déplacement sortie septum	32.13	mm
Champ intégré B*L	1.200	T.m
Induction dans le Gap	0.556	T
Champ magn. H=B/uo	4.43E+05	A/m
Courant nécessaire	13281	A
Valeur efficace du courant	374	A
densité de courant eff.	5.19	A/mm2
Résistance de l'aimant	0.50	mOhms
Inductance de l'aimant	5.43	uH
Puissance dissipée	0.070	kW
Energie stockée	479	J

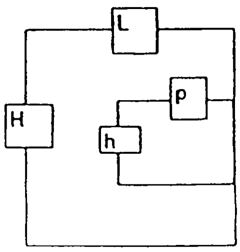


	65	p en mm
	30	h en mm
	130	L en mm
	160	H en mm
Débit d'eau total	0.16	l/min
Débit dans chaque spire	0.16	l/min
vitesse de l'eau (< 10m/s)	0.13	m/s
pression différentielle necess.	2.32	bar
Force septum /cond fond	791.34	daN
Flèche max . septum (appui)	0.005	mm
moment flech.max. (appui)	1.39	mm*daN
contrainte maxi <5 (appui)	0.92	daN/mm2
Masse culasse (sans poutre)	290	kg
longueur d'une spire	3.7714	m
section conduct. refroid.déduit	129.6	mm2
Section refroidissement	5.4	mm2

Appendix 3. Magnet characteristics for proton operation at 26 GeV/c, deflection 30 mrad

DONNEES		
particules electrons : e protons : p	p	
quant.mouvt : MV Energie cin. : EC	MV	
Quantité de mouvement p =	26	GeV/c
Déflexion requise	30	mrad
Epaisseur du septum	3	mm
Hauteur du Gap	30	mm
Profondeur du Gap	65	mm
Longueur de la culasse	2.142	m
Espace de glissement	0	m
nombre de spires	1	spire
Hauteur de chaque conducteur	30	mm
Largeur de chaque conducteur	4.5	mm
Résistivité du cuivre (1.72E-2	0.0172	mO.mm
module d'Elasticité (12500	12500	daN/mm2
Forme de l'impulsion		
DC , 1/2 sinus : S , trapèze : T	S	
1/2 période de l'impulsion	3.8	ms
Période de récurence (cycle tot.	2.4	s
soit le taux de répétition		
% du conducteur pour refroidissement	4	%
Elévation de température moy.admise	5	oC
ex: AA avec dT =20 Temp.max=60oC		

RESULTATS	PROTONS	
Masse au repos mo	0.94	Gev/c2
Energie cinétique	25.0770	GeV
Quantité de mouvement	26.0000	Gev/c
beta	0.9993	
gamma	27.6776	
beta*gamma	27.6596	
Déplacement sortie septum	32.13	mm
Champ Intégré B*L	2.600	T.m
Induction dans le Gap	1.205	T
Champ magn. H=B/uo	9.59E+05	A/m
Courant nécessaire	28776	A
Valeur efficace du courant	810	A
densité de courant eff.	11.25	A/mm2
Résistance de l'aimant	0.50	mOhms
Inductance de l'aimant	5.43	uH
Puissance dissipée	0.328	kW
Energie stockée	2246	J



65	p en mm
30	h en mm
130	L en mm
160	H en mm

Débit d'eau total	0.76	l/min
Débit dans chaque spire	0.76	l/min
vitesse de l'eau (< 10m/s)	0.62	m/s
pression différentielle necess	10.89	bar
Force septum /cond fond	3714.90	daN
Flèche max . septum (appui)	0.022	mm
moment flech.max. (appui)	6.50	mm*daN
contrainte maxi <5 (appui)	4.34	daN/mm2
Masse culasse (sans poutre)	290	kg
longueur d'une spire	3.7714	m
section conduct. refroid.déduit	129.6	mm2
Section refroidissement	5.4	mm2