EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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PS/ CA/ Note 98-17

# INITIAL MEASUREMENTS OF THE BOOSTER HORIZONTAL EJECTION MAGNETIC SEPTUM (BESMH)

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# 1. Introduction

In the frame work of the project “PS for LHC” the Booster energy is to be increased from 1 GeV to 1.4 GeV. Over the past few years already a septum magnet in the transfer line to the PS (BTSMV 20), and the septum injection magnet in the PS ring have been modified to handle the increased beam energy. These new generation septum magnets have been constructed as pulsed current magnets, instead of DC current magnets as previously installed. During the shut down of January 1998 the Booster Horizontal Ejection Septum Magnet (referred to as BESMH) was replaced by a pulsed current version, capable of handling the increased beam energies. This report describes the initial tests of these magnets and their spares.

# 2. The layout of the BESMH

The BESMH is the ejection septum of the Booster accelerator. Since the Booster consists of 4 accelerator rings stacked on top of each other, the ejection is done with 4 ejection septa magnets stacked on top of each other. Unlike before, when one rectangular vacuum tank was used, two circular vacuum tanks are used to house each two septa magnets. In appendix 1 the layout of the septa magnets is shown as seen from the exterior of the accelerator rings. To the left is the beam observation tank covering the four rings at the same time, with the beam observation screens. To the right are the two vacuum tanks stacked on top of each other, each containing two septum magnets.

# 3. The measurements

Before installation the magnets were tested. The magnets are installed per pair in a vacuum tank and are connected in series. In the final assembly the two tanks are stacked on top of each other and the two tanks are connected in series as well. The magnetic measurements were done per tank. The same transformer was used as in the final assembly with four magnets in series, and a similar capacitor of 3 mF was used. To approach the required 3 ms half sine pulse length and extra self inductance L was introduced on the primary site of the transformer. This resulted in the circuit diagram as shown in figure 1.

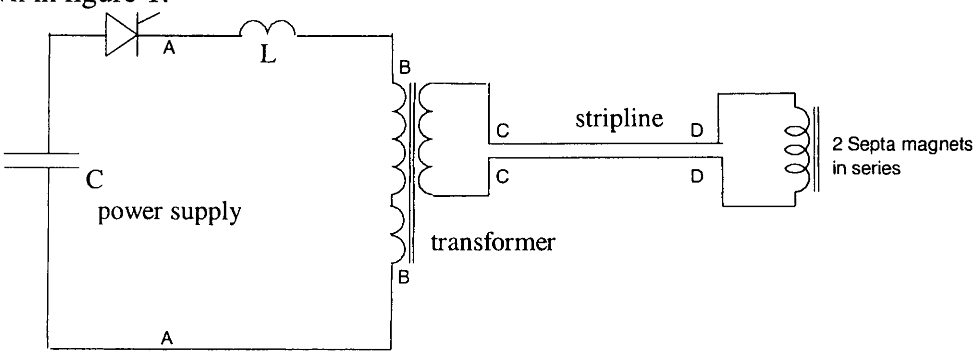



Figure 1: The circuit diagram

The circuit specifications were:

| | |
|---|---|
| Capacitance C | 3 mF |
| Inductance L | 200 μH |
| Transformer | 4 : 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 |

## 3.1 Inductance measurements

Using the H.P. impedance meter the values of resistance and inductance was measured at point A in the circuit diagram. This implied the impedance of 2 magnets BESMH in series, i.e. 1 tank, as seen on the primary of the transformer in the power supply, including the additional self inductance L, have been measured. A second measurement was taken when a short circuit was made at point D. This allows to derive the inductance and resistance of the magnets per tank. In table 1 the results are reproduced.

Table 1: The impedance of 2 magnets in series (1 tank) as from the feedthrough of the tank

| Impedance | R (mΩ) | L (μH) |
|---|---|---|
| No short at D | 53 | 365 |
| Short circuit at D | 34 | 244 |
| **Derived per tank of 2 Septa magnet s** | **1.2** | **7.56** |

The theoretical value of the inductance per magnet is 3.9 μH (see appendix 2 for the theoretical precalculations of the magnet) so the measured value is slightly lower than expected, despite the additional stripline in the vacuum tank to connect the two magnets in series.

## 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.

The gap field

In appendix 3 the results of all magnetic measurements are shown. The equivalent magnetic length as derived from these measurements is shown in table 2. The equivalent magnetic length of all the magnets is 949 mm with a measurement error of roughly 5 mm mainly due to the alignment error of the measurement coils. A three dimensional finite element calculation predicted 946 mm, so this value falls within the range of measurement error around the measured value. The model used for the finite element calculation is described in CERN Note PS / CA / 97 – 27.

Table 2: Resume of magnetic equivalent lengths as measured at different currents for each magnet

| Magnet number, identical to coil number | Lowest measurement (mm) | Highest measurement (mm) |
|---|---|---|
| 1 | 948 | 951 |
| 2 | 944 | 949 |
| 3 | 949 | 952 |
| 4 | 949 | 953 |
| 5 | 948 | 952 |
| 6 | 949 | 955 |
| 7 | 950 | 954 |
| 8 | 948 | 951 |

The fringe field

Also the integrated fringe field, the field next to the septum conductor outside the gap, has been measured. The results are reproduced in appendix 3, and in figure 2 the relative fringe field with respect to the gap field at 7.1 kA is illustrated as function of the distance to the septum. What can be noticed is that the magnet for ring 1 has a far lower fringe field than the other magnets. This can be explained by the fact that the building tolerances are low, and a small difference in play between the yoke of the magnet and the septum conductor has great influence on the fringe field. The same diagram for the spare magnet as shown in appendix 3, shows there is little difference between the magnets.

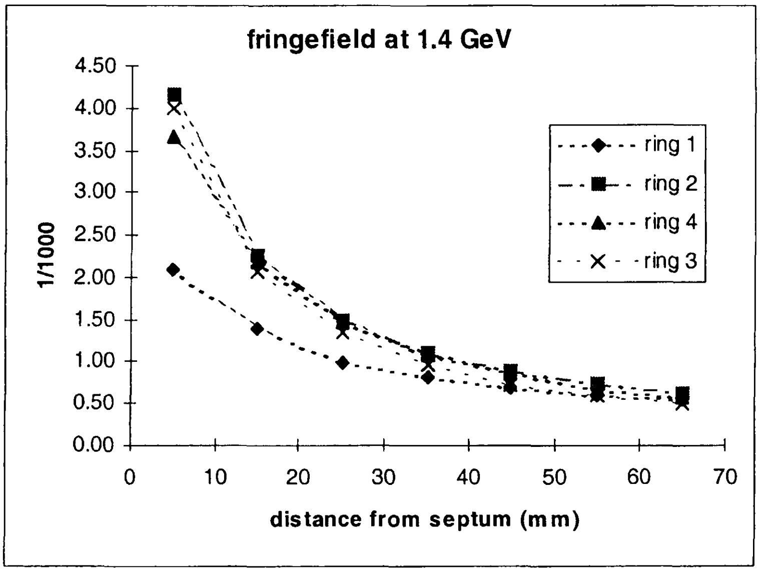



Figure 2: The relative fringe field at 7.1 kA for the BESMH magnets as installed in the Booster in January 1998

The end field

For completeness also the end field was measured for the different magnets. The end field is measured in the middle of the gap, starting at the magnet extremity moving outwards, into the air. The leak field measured over there, is taken into account when doing the integrated gap field measurement, but was measured punctually for verification purposes. The results are tabulated in appendix 3.

## 3.3 Miscellaneous

In appendix 4 the identification of the coils, tanks and feedthroughs is well indicated for future reference. Also the water flow per tank is mentioned as measured at 15 bar.

To support the last magnetic steel lamination at the extremities, next to the cross over conductors, all BESMH magnets have a 1.5 mm stainless steel non magnetic lamination at these ends installed, to prevent movement of the last magnetic gap lamination due to the pulsing magnetic fields. However only the spare magnet assembly has the Vespel clamping plates installed to provide additional support to this stainless steel lamination. The layout of this mechanical support is of identical layout as the ones described in note CERN PS / CA / Note 98 – 11 for the modified SMH 16.

For the record also the water flow tests have been included in appendix 5. What can be noticed is that there is no wide spread in flow rate at a given pressure between the various coils. Except for coil number 9 the flow rate variation between the coils is lower than 3 % at the same pressure. Coil 9 the values measured are some 12 % lower than the other coils, and this is likely due to a local restriction in the cooling tubes, caused by too much brazing. However the cooling capacity is still considered as sufficient. For all the coils, except number 9, the measured flow corresponds within 5% of the calculated flow rate.

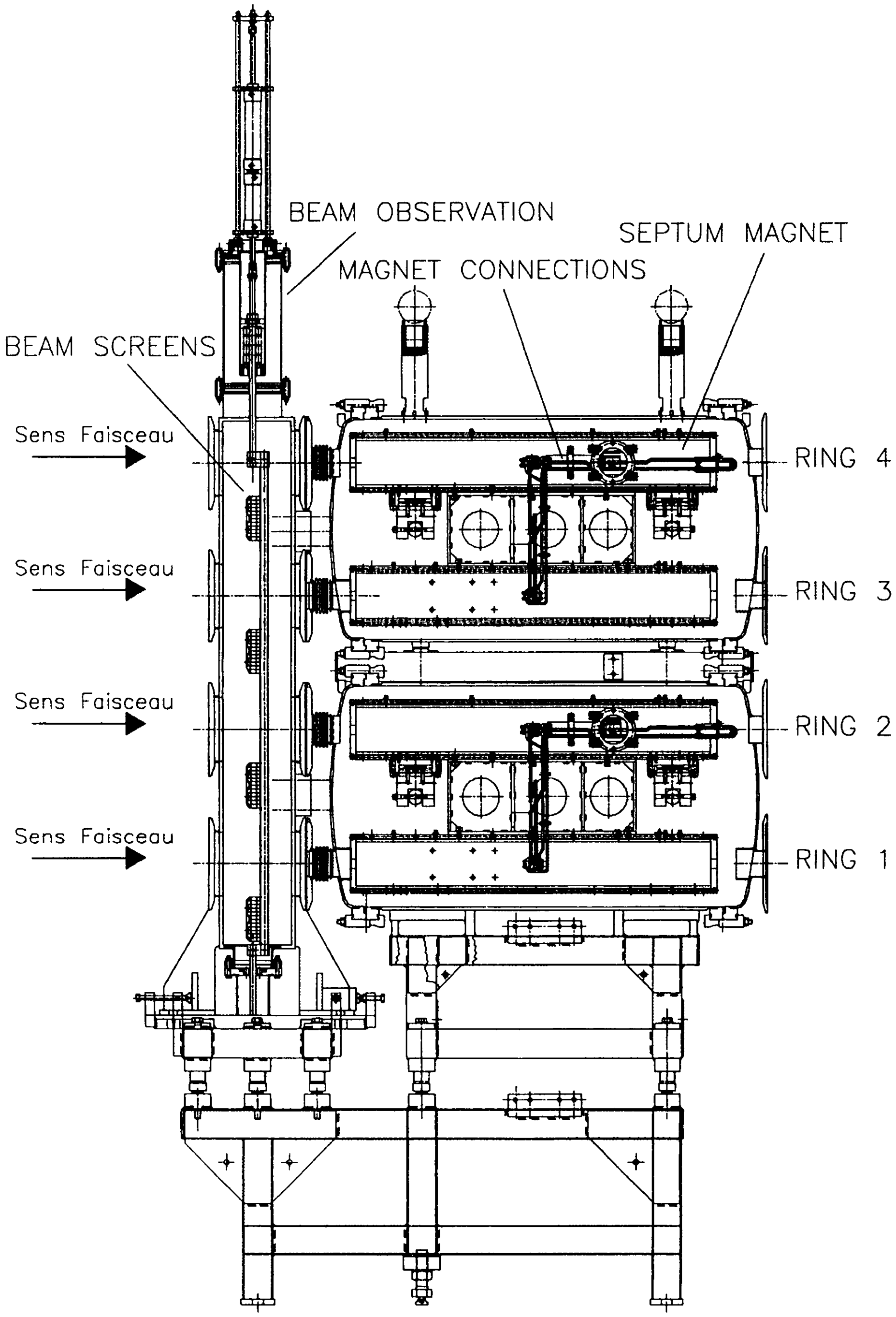
## 4. Conclusions

The BESMH magnets have been tested before installation in the Booster in January 1998. The magnetic equivalent length was found to be 949 ± 5 mm, which corresponds closely with the calculated length of 946 mm.

The fringe field was measured as well. The integrated fringe field for a typical magnet is 1 ‰ of the integrated gap field at 40 mm from the septum conductor. But at only 5 mm from the septum blade the integrated fringe field is typically 4 ‰ of the integrated gap field. This can be considered as a relatively low increase and is due to the use of a FeNi (50/50%) magnetic screen next to the septum conductor.

The inductance measurements show a value of 7.6 μH per tank as measured from the feedthrough. This corresponds with two magnets in series, and the measured value is slightly lower than what could be expected theoretically. This is likely due to the use of less suitable measurement equipment.

**Appendix 1**. Layout of BESMH for the four Booster accelerator rings



## **Appendix 2.** Magnet characteristics for proton operation

- Magnet pre calculations for 800 MeV protons
- Magnet pre calculations for 1.0 GeV protons
- Magnet pre calculations for 1.4 GeV protons
- Magnet pre calculations for 2.0 GeV protons

Sepmcmon

M.THIVENT Version 12 Mai 1992 Edition du : 28.Oct.97

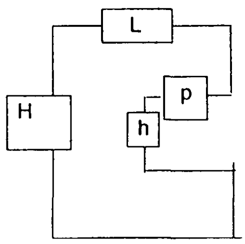
Modifie R, L pour monospire, hydraulique revise 2/8/94 J. Borburgh

PREDETERMINATION SEPTUM MAGNETIQUE SMCALC.XLS **PW prot:jb**

# BESMH

## particularités

| DONNEES | | | RESULTATS | PROTONS | |
|---|---|---|---|---|---|
| particules electrons : e protons : p | **p** | | Masse au repos mo | 0.94 | Gev/c2 |
| quant.mouvt : MV Energie cin. : EC | **ec** | | **Energie cinétique** | **0.8000** | GeV |
| | | | **Quantité de mouvement** | **1.4642** | Gev/c |
| **Energie cinétique Ec =** | **0.8** | GeV | beta | 0.8415 | |
| | | | gamma | 1.8511 | |
| **Déflexion requise** | **47** | mrad | beta*gamma | 1.5577 | |
| **Epaisseur du septum** | **3** | mm | Déplact. après espace de gliss | **22.09** | mm |
| Hauteur du Gap | **25** | mm | | | |
| Profondeur du Gap | **89** | mm | **Champ intégré B*L** | **0.229** | T.m |
| Longueur magnetique equivalent | **940** | mm | **Induction dans le Gap** | **0.244** | T |
| Espace de glissement | 0 | m | Champ magn. H=B/uo | 1.94E+05 | A/m |
| **Monospire donc** | **1** | spire | **Courant nécessaire** | **4855** | A |
| Epaisseur cond. retour | 7.6 | mm | Valeur efficace du courant | 183 | A |
| Hauteur de conducteur retour | 25 | mm | densité de courant eff. | **2.66** | A/mm2 |
| Résistivité du cuivre ( 1.72E-2 | 0.0172 | mO.mm | **Résistance de l'aimant** | **0.365** | mOhms |
| module d'Elasticité (12500 | 12500 | daN/mm2 | **Inductance de l'aimant** | **3.95** | uH |
| **Forme de l'impulsion** | | | **Puissance dissipée** | **0.012** | kW |
| DC , 1/2 sinus : S , trapèze : T | **S** | | Energie stockée | 47 | J |
| 1/2 période de l'impulsion | **3.4** | ms | | | |
| **Période de récurence (cycle tot.** | **1.2** | s | | | |
| taux de répétition de l'impulsion de courant | | | | 89 | p en mm |
| **Systeme de refroidissement** | | | | 25 | h en mm |
| pression différentielle | **12** | bar | | | |
| nombre du circuits | **2** | | | 108.7 | L en mm |
| *septum* | | | | | |
| forme element de refroidissement | **rec** | | | 64.5 | H en mm |
| Cote horizontal | **3** | mm | | | |
| Cote vertical | **12.5** | mm | | | |
| forme du passage d'eau | **circ** | | Débit d'eau total | **3.67** | l/min |
| Diametre trou | **2** | mm | Débit dans chaque spire | 1.84 | l/min |
| | | | vitesse de l'eau dans septum | 9.75 | m/s |
| *conducteur retour* | | | dT total d'eau | 0.05 | K |
| forme element de refroidissement | **rec** | | | | |
| Cote horizontal (mm) | **7.6** | mm | **Force septum /cond fond** | **55.69** | daN |
| Cote vertical (mm) | **12.5** | mm | Flèche max . septum (appui | 0.000 | mm |
| forme du passage d'eau | **carre** | | moment flech.max. ( appui | 0.19 | mm*daN |
| Cote horizontal | **2** | mm | contrainte maxi <5 (appui | 0.12 | daN/mm2 |
| | | | Masse culasse (sans poutre | **32** | **kg** |
| **Matiere** | | | section cond. septum | 68.71681469 | mm2 |
| maximum admissible champ dans le f | **1.1** | T | Section refroidissement septur | 6.283185307 | mm2 |



## **Appendix 3.** Magnetic measurement results

- Magnetic measurements in the gap
- Magnetic measurements of the fringe field
- Magnetic measurements of the end field

gap

# Besmh

T_half sine = 3.65 ms

| | | | | | |
|---|---|---|---|---|---|
| coil 1 | dia. 5 | mm; | 0.03693 m2 | (Bo) | |
| coil 2 | l=1300 | mm | 0.05769 m2/m | (Bdl) | 0.0750 m2 |

**magnet 1** date test 18/11/97

| I (A) | coil1 Vdt | mT | cal | coil2 Vdt | mTm | cal | Leq mm | remarks |
|---|---|---|---|---|---|---|---|---|
| 4855 | 8.979E-03 | 243.1 | 244.0 | 1.334E-02 | 231.2 | 229.0 | 0.951 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.033E-02 | 279.7 | 283.0 | 1.534E-02 | 265.8 | 266.0 | 0.950 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.336E-02 | 361.8 | 357.0 | 1.979E-02 | 343.0 | 336.0 | 0.948 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.702E-02 | 461.0 | 464.0 | 2.523E-02 | 437.4 | 436.0 | 0.949 | angle 47 mrad with protons at 2.0 GeV |

**magnet2** date test 18/11/97

| I (A) | coil1 Vdt | mT | cal | coil2 Vdt | mTm | cal | Leq mm | remarks |
|---|---|---|---|---|---|---|---|---|
| 4855 | 9.039E-03 | 244.8 | 244.0 | 1.333E-02 | 231.0 | 229.0 | 0.944 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.038E-02 | 281.1 | 283.0 | 1.540E-02 | 266.9 | 266.0 | 0.949 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.316E-02 | 356.4 | 357.0 | *1.249E-02* | *338.2* | 336.0 | 0.949 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.700E-02 | 460.4 | 464.0 | 2.521E-02 | 437.0 | 436.0 | 0.949 | angle 47 mrad with protons at 2.0 GeV |

**magnet6** date test 5/12/97

| I (A) | coil1 Vdt | mT | cal | coil2 Vdt | mTm | cal | Leq mm | remarks |
|---|---|---|---|---|---|---|---|---|
| 4855 | 8.917E-03 | 241.5 | 244.0 | 1.330E-02 | 230.6 | 229.0 | 0.955 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.039E-02 | 281.4 | 283.0 | 1.548E-02 | 268.4 | 266.0 | 0.954 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.307E-02 | 354.0 | 357.0 | 1.938E-02 | 335.9 | 336.0 | 0.949 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.699E-02 | 460.0 | 464.0 | 2.527E-02 | 438.1 | 436.0 | 0.952 | angle 47 mrad with protons at 2.0 GeV |

**magnet4**

| I (A) | coil1 Vdt | mT | cal | coil2 Vdt | mTm | cal | Leq mm | remarks |
|---|---|---|---|---|---|---|---|---|
| 4855 | 8.980E-03 | 243.2 | 244.0 | 1.331E-02 | 230.7 | 229.0 | 0.949 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.051E-02 | 284.5 | 283.0 | 1.562E-02 | 270.8 | 266.0 | 0.952 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.329E-02 | 360.0 | 357.0 | 1.979E-02 | 343.0 | 336.0 | 0.953 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.698E-02 | 459.6 | 464.0 | 2.523E-02 | 437.4 | 436.0 | 0.952 | angle 47 mrad with protons at 2.0 GeV |

gap

**magnet 3** date test 17/3/98

| I | coil1 | | | coil2 | | | Leq | remarks |
|---|---|---|---|---|---|---|---|---|
| (A) | Vdt | mT | cal | Vdt | mTm | cal | mm | |
| 4855 | 8.84E-03 | 239.5 | 244.0 | 1.312E-02 | 227.3 | 229.0 | 0.949 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.03E-02 | 278.7 | 283.0 | 1.526E-02 | 264.6 | 266.0 | 0.949 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.31E-02 | 353.8 | 357.0 | 1.938E-02 | 335.9 | 336.0 | 0.949 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.701E-02 | 460.7 | 464.0 | 2.530E-02 | 438.6 | 436.0 | 0.952 | angle 47 mrad with protons at 2.0 GeV |

**magnet 5** date test 16/3/98 superieur / enceinte inf.

| I | coil1 | | | coil2 | | | Leq | remarks |
|---|---|---|---|---|---|---|---|---|
| (A) | Vdt | mT | cal | Vdt | mTm | cal | mm | |
| 4855 | 8.843E-03 | 239.5 | 244.0 | 1,309e-2 | 227.0 | 229.0 | 0.948 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.024E-02 | 277.3 | 283.0 | 1.524E-02 | 264.1 | 266.0 | 0.952 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.308E-02 | 354.2 | 357.0 | 1.937E-02 | 335.7 | 336.0 | 0.948 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.688E-02 | 457.0 | 464.0 | 2.507E-02 | 434.5 | 436.0 | 0.951 | angle 47 mrad with protons at 2.0 GeV |

**magnet 7** date test 29/6/98 superieur / enceinte sup.

| I | coil1 | | | coil2 | | | Leq | remarks |
|---|---|---|---|---|---|---|---|---|
| (A) | Vdt | mT | cal | Vdt | mTm | cal | mm | |
| 4855 | 8.917E-03 | 241.5 | 244.0 | 1.331E-02 | 230.4 | 229.0 | 0.954 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.032E-02 | 279.3 | 283.0 | 1.537E-02 | 266.4 | 266.0 | 0.954 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.302E-02 | 352.5 | 357.0 | 1.931E-02 | 334.8 | 336.0 | 0.950 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.694E-02 | 458.6 | 464.0 | 2.516E-02 | 436.0 | 436.0 | 0.951 | angle 47 mrad with protons at 2.0 GeV |

**magnet 8** date test 29/6/98 inferieur / enceinte sup.

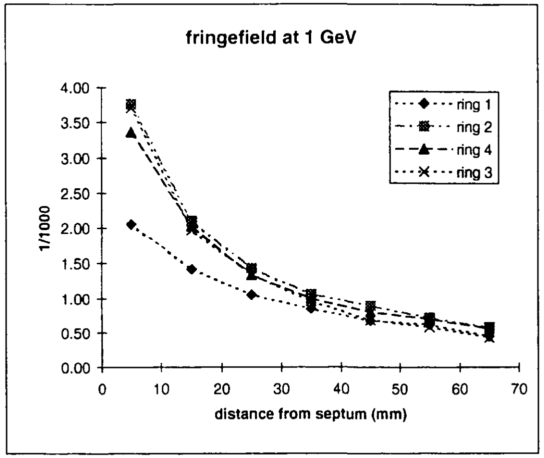
| I | coil1 | | | coil2 | | | Leq | remarks |
|---|---|---|---|---|---|---|---|---|
| (A) | Vdt | mT | cal | Vdt | mTm | cal | mm | |
| 4855 | 8.876E-03 | 240.4 | 244.0 | 1.317E-02 | 228.2 | 229.0 | 0.949 | angle 47 mrad with protons at 0.8 GeV |
| 5627 | 1.034E-02 | 280.0 | 283.0 | 1.537E-02 | 266.4 | 266.0 | 0.951 | angle 47 mrad with protons at 1.0 GeV |
| 7105 | 1.308E-02 | 354.3 | 357.0 | 1.942E-02 | 336.6 | 336.0 | 0.950 | angle 47 mrad with protons at 1.4 GeV |
| 9237 | 1.694E-02 | 458.8 | 464.0 | 2.509E-02 | 435.0 | 436.0 | 0.948 | angle 47 mrad with protons at 2.0 GeV |

# Fringefield BESMH

| | | | |
|---|---|---|---|
| coil 2 | l=1300 | mm | 0.05769 m2/m |
| coil 3 | l=1300 | mm | 0.05808 m2/m |

magnet 1 date test: 18/11/97 ring 1

| distance to septum (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 @ 1gev | 1/1000 @ 1.4 gev |
|---|---|---|---|---|---|---|---|
| 5 | 3.15E-05 | 0.5457 | 4.14E-05 | 0.7179 | coil2 | 2.05 | 2.09 |
| 15 | 2.17E-05 | 0.3765 | 2.77E-05 | 0.4793 | coil2 | 1.42 | 1.40 |
| 25 | 1.61E-05 | 0.2792 | 1.96E-05 | 0.3386 | coil2 | 1.05 | 0.99 |
| 35 | 1.30E-05 | 0.2259 | 1.61E-05 | 0.2792 | coil2 | 0.85 | 0.81 |
| 45 | 1.03E-05 | 0.1782 | 1.40E-05 | 0.2426 | coil2 | 0.67 | 0.71 |
| 55 | 9.43E-06 | 0.1634 | 1.20E-05 | 0.2073 | coil2 | 0.61 | 0.60 |
| 65 | 6.94E-06 | 0.1203 | 1.11E-05 | 0.1918 | coil2 | 0.45 | 0.56 |

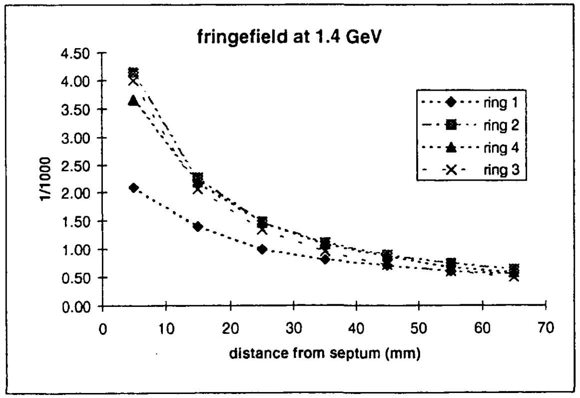



magnet 2 date test: 18/11/97 ring 2

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 5.79E-05 | 1.004 | 8.10E-05 | 1.404 | coil2 | 3.76 | 4.15 |
| 15 | 3.23E-05 | 0.5601 | 4.42E-05 | 0.7653 | coil2 | 2.10 | 2.26 |
| 25 | 2.21E-05 | 0.3822 | 2.90E-05 | 0.5024 | coil2 | 1.43 | 1.49 |
| 35 | 1.63E-05 | 0.282 | 2.15E-05 | 0.3734 | coil2 | 1.06 | 1.10 |
| 45 | 1.37E-05 | 0.2383 | 1.75E-05 | 0.3031 | coil2 | 0.89 | 0.90 |
| 55 | 1.11E-05 | 0.1921 | 1.48E-05 | 0.2561 | coil2 | 0.72 | 0.76 |
| 65 | 8.90E-06 | 0.1542 | 1.24E-05 | 0.2151 | coil2 | 0.58 | 0.64 |

magnet 6 date test 5/12/97 ring 3

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 5.74E-05 | 0.9884 | 7.87E-05 | 1.354 | coil3 | 3.70 | 4.00 |
| 15 | 3.06E-05 | 0.5268 | 4.05E-05 | 0.6964 | coil3 | 1.97 | 2.06 |
| 25 | 2.09E-05 | 0.3594 | 2.65E-05 | 0.4565 | coil3 | 1.35 | 1.35 |
| 35 | 1.48E-05 | 0.2549 | 1.89E-05 | 0.3252 | coil3 | 0.96 | 0.96 |
| 45 | 1.06E-05 | 0.183 | 1.42E-05 | 0.244 | coil3 | 0.69 | 0.72 |
| 55 | 9.05E-06 | 0.1558 | 1.19E-05 | 0.2057 | coil3 | 0.58 | 0.61 |
| 65 | 6.65E-06 | 0.1144 | 9.91E-06 | 0.1707 | coil3 | 0.43 | 0.50 |




magnet 4 test date 5/12/97 ring 4

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 5.18E-05 | 0.8979 | 7.13E-05 | 1.2352 | coil3 | 3.36 | 3.65 |
| 15 | 3.13E-05 | 0.5424 | 4.27E-05 | 0.7398 | coil3 | 2.03 | 2.19 |
| 25 | 2.06E-05 | 0.3569 | 2.87E-05 | 0.4980 | coil3 | 1.34 | 1.47 |
| 35 | 1.54E-05 | 0.2664 | 2.12E-05 | 0.3677 | coil3 | 1.00 | 1.09 |
| 45 | 1.23E-05 | 0.2139 | 1.71E-05 | 0.2957 | coil3 | 0.80 | 0.87 |
| 55 | 1.08E-05 | 0.1867 | 1.32E-05 | 0.2279 | coil3 | 0.70 | 0.67 |
| 65 | 8.59E-06 | 0.1489 | 1.13E-05 | 0.1957 | coil3 | 0.56 | 0.58 |

magnet 3 date test 17/3/98 ring 1

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 5.94E-05 | 1.029 | 7.85E-05 | 1.361 | coil 2 | 3.86 | 4.02 |
| 15 | 3.00E-05 | 0.5207 | 4.32E-05 | 0.7484 | coil 2 | 1.95 | 2.21 |
| 25 | 2.00E-05 | 0.347 | 2.97E-05 | 0.5142 | coil 2 | 1.30 | 1.52 |
| 35 | 1.46E-05 | 0.253 | 1.97E-05 | 0.3414 | coil 2 | 0.95 | 1.01 |
| 45 | 1.10E-05 | 0.1908 | 1.61E-05 | 0.2787 | coil 2 | 0.71 | 0.82 |
| 55 | 8.90E-06 | 0.1544 | 1.18E-05 | 0.2051 | coil 2 | 0.58 | 0.61 |
| 65 | 7.96E-06 | 0.138 | 9.11E-06 | 0.1579 | coil 2 | 0.52 | 0.47 |

magnet 5 test date 16/3/98 ring 2 superieur/ enceinte inf.

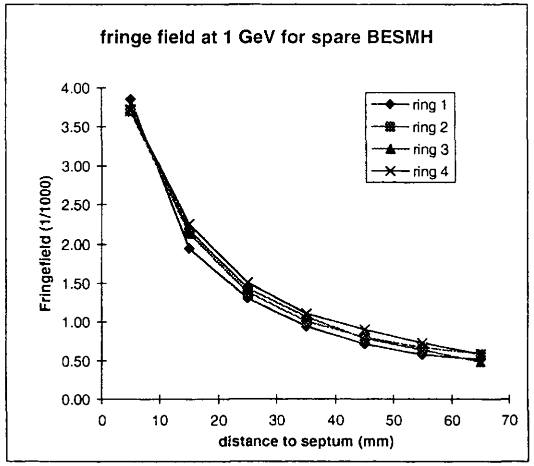
| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 3.63E-05 | 0.976 | 7.68E-05 | 1.331 | coil 2 | 3.70 | 3.96 |
| 15 | 3.29E-05 | 0.563 | 4.24E-05 | 0.736 | coil 2 | 2.13 | 2.19 |
| 25 | 2.12E-05 | 0.367 | 2.85E-05 | 0.494 | coil 2 | 1.39 | 1.47 |
| 35 | 1.54E-05 | 0.267 | 2.05E-05 | 0.354 | coil 2 | 1.01 | 1.06 |
| 45 | 1.22E-05 | 0.2122 | 1.56E-05 | 0.2703 | coil 2 | 0.80 | 0.81 |
| 55 | 1.03E-05 | 0.1791 | 1.31E-05 | 0.2262 | coil 2 | 0.68 | 0.67 |
| 65 | 8.95E-06 | 0.1551 | 1.07E-05 | 0.1870 | coil 2 | 0.59 | 0.56 |

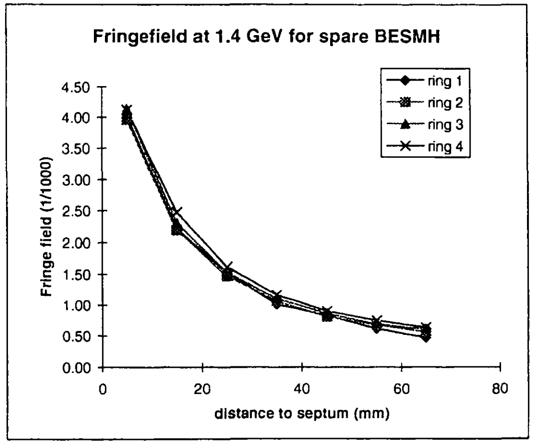
magnet 7 date test 29/6/98 ring 3

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 5.80E-05 | 0.9987 | 8.12E-05 | 1.399 | coil3 | 3.74 | 4.14 |
| 15 | 3.38E-05 | 0.5813 | 4.53E-05 | 0.7796 | coil3 | 2.18 | 2.31 |
| 25 | 2.22E-05 | 0.382 | 2.98E-05 | 0.5128 | coil3 | 1.43 | 1.52 |
| 35 | 1.66E-05 | 0.2858 | 2.16E-05 | 0.3714 | coil3 | 1.07 | 1.10 |
| 45 | 1.23E-05 | 0.2114 | 1.68E-05 | 0.2898 | coil3 | 0.79 | 0.86 |
| 55 | 1.00E-05 | 0.1726 | 1.35E-05 | 0.2322 | coil3 | 0.65 | 0.69 |
| 65 | 7.46E-06 | 0.1284 | 1.18E-05 | 0.2027 | coil3 | 0.48 | 0.60 |

magnet 8 date test 29/6/98 ring 4

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | Bdl (mT.m) | Vdt (V.s) 1.4 GeV, 7.1 kA | Bdl (mT.m) | | 1/1000 | 1/1000 |
|---|---|---|---|---|---|---|---|
| 5 | 5.77E-05 | 0.9938 | 8.11E-05 | 1.396 | coil3 | 3.72 | 4.13 |
| 15 | 3.49E-05 | 0.6016 | 4.86E-05 | 0.8367 | coil3 | 2.25 | 2.47 |
| 25 | 2.34E-05 | 0.4026 | 3.15E-05 | 0.5428 | coil3 | 1.51 | 1.60 |
| 35 | 1.72E-05 | 0.2967 | 2.27E-05 | 0.3914 | coil3 | 1.11 | 1.16 |
| 45 | 1.41E-05 | 0.2423 | 1.76E-05 | 0.3027 | coil3 | 0.91 | 0.90 |
| 55 | 1.14E-05 | 0.1966 | 1.47E-05 | 0.2526 | coil3 | 0.74 | 0.75 |
| 65 | 9.13E-06 | 0.1571 | 1.24E-05 | 0.2135 | coil3 | 0.59 | 0.63 |



# ENDFIELD besmh

coil 1 dia. 5 mm; 0.03693 m2

**magnet 1** date test: 18/11/97

| distance to endplate (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) | tosca |
|---|---|---|---|---|---|
| 0 | 1.46E-04 | 3.9650 | 1.91E-04 | 5.1770 | 1.151 |
| 10 | 6.85E-05 | 1.8540 | 8.70E-05 | 2.3570 | 0.1807 |
| 20 | 3.58E-05 | 0.9690 | 4.40E-05 | 1.1930 | 5.60E-05 |
| 30 | 2.01E-05 | 0.5440 | 2.58E-05 | 0.6979 | |
| 40 | 1.29E-05 | 0.3492 | 1.65E-05 | 0.4465 | |
| 50 | 8.24E-06 | 0.2231 | 1.12E-05 | 0.3038 | |
| 60 | 6.02E-06 | 0.1630 | 7.12E-06 | 0.1927 | |

**magnet 2** date test: 18/11/97

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.57E-05 | 4.2580 | 1.95E-04 | 5.2680 |
| 10 | 7.25E-05 | 1.9620 | 8.85E-05 | 2.3960 |
| 20 | 3.53E-05 | 0.9566 | 4.36E-05 | 1.1810 |
| 30 | 1.97E-05 | 0.5345 | 2.39E-05 | 0.6479 |
| 40 | 1.16E-05 | 0.3142 | 1.46E-05 | 0.3953 |
| 50 | 7.15E-06 | 0.1937 | 8.88E-06 | 0.2405 |
| 60 | 4.16E-06 | 0.1217 | 5.36E-06 | 0.1451 |

**magnet 6** date test 5/12/97

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.46E-04 | 3.9390 | 1.88E-04 | 5.0840 |
| 10 | 6.65E-05 | 1.8010 | 8.55E-05 | 2.3160 |
| 20 | 3.44E-05 | 0.9326 | 4.44E-05 | 1.2030 |
| 30 | 2.01E-05 | 0.5448 | 2.55E-05 | 0.6907 |
| 40 | 1.32E-05 | 0.3576 | 1.63E-05 | 0.4401 |
| 50 | 8.43E-06 | 0.2284 | 1.11E-05 | 0.3010 |
| 60 | 6.40E-06 | 0.1732 | 8.10E-06 | 0.2193 |

**magnet 4** test date 5/12/97

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.68E-04 | 4.546 | 2.08E-04 | 5.619 |
| 10 | 7.46E-05 | 2.020 | 9.42E-05 | 2.550 |
| 20 | 3.71E-05 | 1.005 | 4.72E-05 | 1.277 |
| 30 | 2.01E-05 | 0.545 | 2.62E-05 | 0.709 |
| 40 | 1.29E-05 | 0.349 | 1.60E-05 | 0.434 |
| 50 | 7.71E-06 | 0.209 | 1.02E-05 | 0.276 |
| 60 | 5.31E-06 | 0.144 | 6.89E-06 | 0.187 |

**magnet 3** test date 17/3/98

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.415E-04 | 3.8320 | 1.84E-04 | 4.9680 |
| 10 | 6.646E-05 | 1.8000 | 8.45E-05 | 2.2870 |
| 20 | 3.495E-05 | 0.9464 | 4.38E-05 | 1.1860 |
| 30 | 2.19E-05 | 0.5920 | 2.61E-05 | 0.7620 |
| 40 | 1.41E-05 | 0.3807 | 1.63E-05 | 0.4408 |
| 50 | 9.52E-06 | 0.2577 | 1.15E-05 | 0.3113 |
| 60 | 7.09E-06 | 0.1920 | 8.53E-06 | 0.2311 |

**magnet 5** test date 17/3/98 superieur/ enceinte inf.

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.33E-04 | 3.595 | 1.78E-04 | 4.811 |
| 10 | 6.09E-05 | 1.649 | 8.07E-05 | 2.185 |
| 20 | 3.17E-05 | 0.858 | 4.28E-05 | 1.158 |
| 30 | 1.91E-05 | 0.516 | 2.40E-05 | 0.6515 |
| 40 | 1.27E-05 | 0.343 | 1.55E-05 | 0.420 |
| 50 | 6.33E-06 | 0.170 | 1.04E-05 | 0.280 |
| 60 | 5.20E-06 | 0.140 | 5.91E-06 | 0.160 |

**magnet 7** test date 29/6/98

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.453E-04 | 3.9350 | 1.93E-04 | 5.2140 |
| 10 | 6.823E-05 | 1.8480 | 9.13E-05 | 2.4710 |
| 20 | 3.518E-05 | 0.9526 | 4.66E-05 | 1.2630 |
| 30 | 1.94E-05 | 0.5250 | 2.61E-05 | 0.7074 |
| 40 | 1.17E-05 | 0.3170 | 1.55E-05 | 0.4203 |
| 50 | 7.91E-06 | 0.2142 | 9.77E-06 | 0.2647 |
| 60 | 4.73E-06 | 0.1282 | 6.61E-06 | 0.1790 |

**magnet 8** test date 29/6/98 superieur/ enceinte su

| d (mm) | Vdt (V.s) 1.0 GeV, 5.6 kA | B (mT) | Vdt (V.s) 1.4 GeV, 7.1 kA | B (mT) |
|---|---|---|---|---|
| 0 | 1.31E-04 | 3.558 | 1.76E-04 | 4.765 |
| 10 | 6.21E-05 | 1.681 | 7.96E-05 | 2.156 |
| 20 | 3.09E-05 | 0.8362 | 3.98E-05 | 1.077 |
| 30 | 1.73E-05 | 0.468 | 2.20E-05 | 0.5946 |
| 40 | 9.98E-06 | 0.270 | 1.29E-05 | 0.349 |
| 50 | 5.88E-06 | 0.159 | 7.87E-06 | 0.213 |
| 60 | 3.03E-06 | 0.082 | 4.85E-06 | 0.131 |

## **Appendix 4.** Magnet numbers, coil and feedthrough identification

| stack | tank | coils | feedthrough | layout |
|---|---|---|---|---|
| 2 | 3 | 1 | PH04 | lower coil, lower tank, ring 1, installed in booster |
| | | 2 | | upper coil, lower tank, ring 2, installed in booster |
| 4 | 4 | 4 | PH05 | upper coil, upper tank, ring 4, installed in booster |
| | | 6 | | lower coil, upper tank, ring 3, installed in booster |
| 3 | 2 | 8 | PH07 | upper coil, upper tank, ring 4, spare |
| | | 7 | | lower coil, upper tank, ring 3, spare |
| 1 | 1 | 3 | PH06 | lower coil, lower tank, ring 1, spare |
| | | 5 | | upper coil, lower tank, ring 2, spare |

Numero stack indiqué sur la poutre de liason entre les deux aimants
Tanks 1 et 2 modifie chez Cinel, pour ratrapper des fautes d'usinage
Tanks 3 et 4 bien construit des le debut.
Les culasses n'ont pas tous un numero. Les aimants suivent les numeros de leurs bobines.

Impedance par tank (a partir de la traversee)

| | |
|---|---|
| L | 7.56 uH |
| R | 1.2 mOhm |

| debit | dP (bar) | Q (l/m) | elletta | facteur de conv. |
|---|---|---|---|---|
| tank 1 | 12 | 1.9 | 7.6 | 0.25 |

**Appendix 5.** Water flow measurements of the coils.

| | **bobine** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | date de test | 31/7/97 | 4/8/97 | | | | | 9/2/98 | 9/2/98 | 10/2/98 | 10/2/98 |
| **dP (bar)** | débit calculé | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** | **dQ (l/min)** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1.32 | 1.30 | 1.34 | 1.31 | 1.31 | 1.32 | 1.34 | 1.31 | 1.30 | 1.17 | 1.30 |
| 4 | 1.96 | 1.96 | 2.00 | 1.97 | 1.95 | 1.92 | 2.00 | 1.92 | 1.90 | 1.68 | 1.89 |
| 6 | 2.47 | 2.48 | 2.51 | 2.50 | 2.42 | 2.46 | 2.50 | 2.39 | 2.40 | 2.10 | 2.42 |
| 8 | 2.9 | 2.88 | 2.92 | 2.87 | 2.85 | 2.86 | 2.90 | 2.84 | 2.84 | 2.50 | 2.80 |
| 10 | 3.31 | 3.24 | 3.28 | 3.23 | 3.20 | 3.19 | 3.25 | 3.16 | 3.16 | 2.77 | 3.16 |
| 12 | 3.67 | 3.64 | 3.61 | 3.55 | 3.56 | 3.53 | 3.59 | 3.42 | 3.40 | 3.04 | 3.40 |
| 16 | 4.3 | 4.10 | 4.14 | 4.04 | 4.14 | 4.14 | 4.20 | 4.14 | 4.41 | 3.54 | 4.20 |