THE MAGNETS FOR THE NEW LOW ENERGY MUON BEAM LINE

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The new low energy muon (LEM) beam transport line consists of 2 solenoids, 3 bending magnets and 12 quadrupole magnets, all of which were designed especially for this application. In addition, the quadrupole magnets can be used as vertical steering magnets. The magnets will be briefly described and depicted.

INTRODUCTION

During 2003, the μE4 beam line was replaced by the new LEM beam line. The main and most challenging new element involved was the large double solenoid placed directly next to the Target E secondary particle production target. Because of the large 500 mm aperture and the solenoidal focusing properties, it will be possible to capture an order of magnitude more secondary particles as compared to the conventional quadrupole triplet, which it replaced. The continuation of the beam line is conventional, consisting of three bending magnets and four triplets. The quadrupole magnets can be also be used as vertical steering magnets. The operational data for all magnets is given in Table 1.

Magnet	WSX61	WSX62	ASR61	ASR62	ASR63	QSM601	QSM612
Bo Gauss	2571	1281	861	773	771	1810	3574
Current Amps	287	143	299	269	263	250	500
Current Max.	420	250	500	500	500	250	500
Voltage Max.	2x98	100	36	34.4	34.4	33.7	68.3
Aperture mm	500	500	240	240	240	400	400
Leff mm	673.3	673.2	758	717	719	393.3	397.3
Length mm	745	745	500	500	500	500	500
Bending Angle			40°	34°	34°		
Weight kg	12'800		1400	1440	1880	2800	2800

Table 1: Operational data for the LEM magnets at 28 MeV/c. The beam line can also be operated at 40 MeV/c.

THE WSX DOUBLE SOLENOID

The design of this element was limited by a number of boundary conditions:

- The intensive radiation environment. This made the use of our proven indirectly cooled mineral insulated cable coil system imperative.
- The space available after removal of the existing quadrupole triplet.
- The new element had to fit on the existing supports, which remained untouched during installation.
- The power and cooling supplies were arranged so that the existing quadrupole triplet remote connectors could be used. This also allowed the existing covering shielding block to be re-used.

Fig. 1: Test assembly of the WSX iron yoke structure.

Fig. 1 shows the iron yoke at various stages of assembly. After the coils are mounted, the vacuum chamber can be inserted into the magnet after temporarily removing the end plates. The coils can be seen during assembly in Fig. 2.

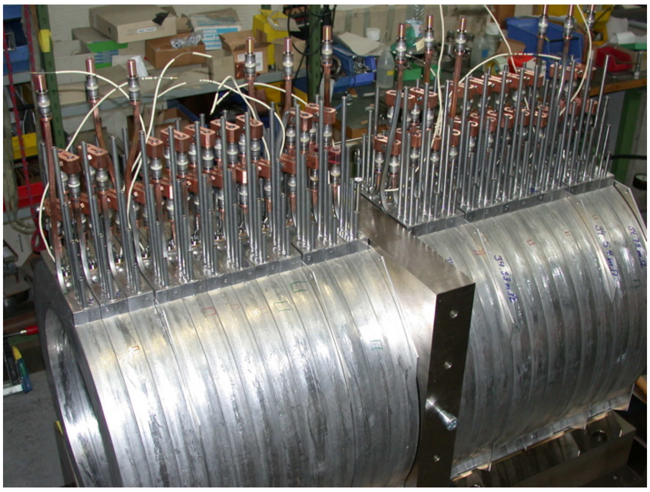

Fig. 2: Each of the two WSX solenoids is powered using 12 coils connected electrically in series.

The 12 coils per solenoid were designed as simple pairs of double pancakes with a shared cooling layer. It would also have been possible to make a single coil but the manufacturing risk involved would have been too high. The coils were manufactured by the Budker Institute in Novosibirsk, Russia. Fig. 5 shows the partially assembled connection system. The complexity is apparent. The possibility to bypass defect coil sections or cooling circuits at the upper service level has been foreseen.

Fig. 3: The assembled WSX double solenoid with vacuum chamber. In operation, two parallel power supplies will be used for WSX61 and one for WSX62.

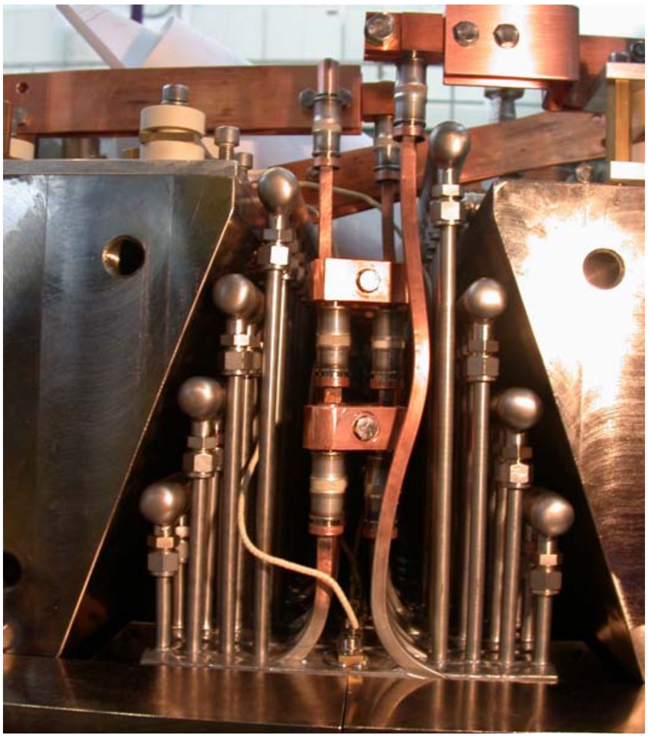

Fig. 4: End view of the connection region.

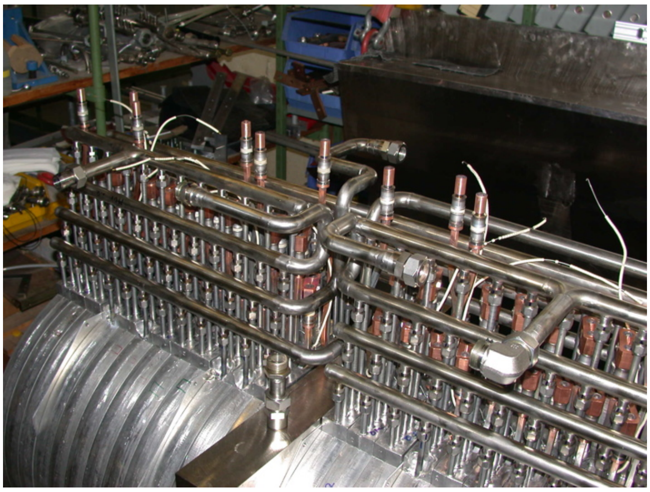

Fig. 5: The WSX stainless steel manifolds provide cooling water to all the coils in parallel. There are four independent water cooling circuits for redundancy.

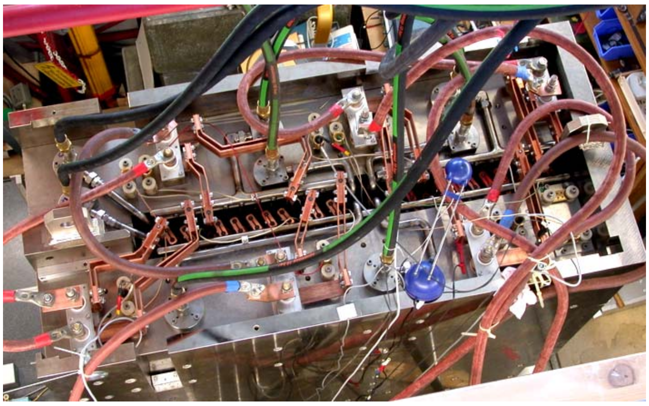

Fig. 6: The assembled WSX double solenoid with temporary power and cooling connections during the magnetic measurement and testing process.

THE LEM QSM QUADRUPOLES

For PSI standards, the QSM quadrupoles are typical. However, the large 400 mm aperture and the short 500 mm total length represent a magnet designer's nightmare. Fortunately, we could copy the earlier QSF design used for the μE5 beam line, which also included quasi-octupole corrections for the geometric aberrations accompanying large angle focusing. In this case, we could use conventional, directly cooled epoxy insulated coils and the classic tipped square yoke geometry. The quadrupoles were manufactured by the Efremov Institute in St. Petersburg, Russia.

In order to ease assembly, an inherent geometrical accuracy was built into the yoke design by machining the yoke and pole from one piece of steel. As a result, three quadrupoles could be accurately positioned on a single base plate without using intermediate positioning feet. Because of the limited space available in the first beam line section; the trolley, which had to fit in the existing hole in the shielding wall was kept unchanged; this proved to be a wise decision. Special attention was placed on the quadrupole triplet, which was placed on the trolley, which would be closest to Target E and which would be very difficult to service. The magnets were not equipped with cooling water manifolds and insulating tubes. Instead, the cooling water and power was supplied through copper tubes, which were necessarily insulated at the magnet voltage. Each quadrupole required five tubes of two different dimensions. Two of the tubes are thick-walled and also carry the excitation current of up to 250 Amps. The electrical connectors and the manifolds with the insulating nylon tubes were placed at the back end of the trolley. Fig. 7 shows the first triplet on its base plate during assembly.

Fig. 7: The first triplet on its base plate during assembly. The mirror plates have not yet been mounted.

Fig. 8: The first QSM triplet installed on the trolley showing the copper cooling water and power supply tubes.

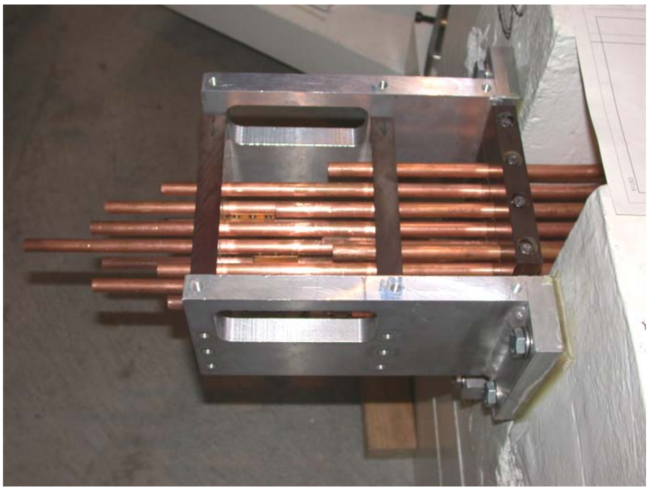

Fig. 9: The copper connection tubes for the first QSM triplet emerging from the end of the trolley.

In Fig. 8, we can see the copper tubes that supply cooling water and power to each quadrupole of the first QSM triplet. Figs. 9 and 10 show the tubes emerging from the end of the trolley before and after the connectors were mounted. The main power cables come from below but were not yet installed. The connections are arranged to allow the possibility of applying extra current to two of the four coils, so that a vertical steering effect can be achieved. Two of the quadrupoles can steer upwards and one downwards. There was no room for separate steering magnets and this feature may prove useful if any displacement of the solenoid axis produces unwanted steering effects. The first beam tests indicate that this will probably not be required.

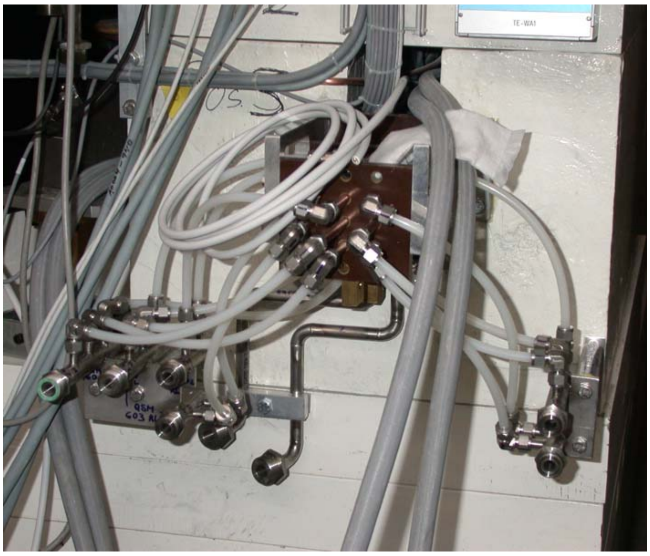

Fig. 10: The power and cooling water connections for the first QSM triplet and the ASR61 bending magnet.

THE LEM ASR DIPOLES

The three LEM dipoles are low field magnets and they are all different. Because of the low field levels, we could use some scrap iron for the yokes with extended poles to achieve the required effective lengths. The first dipole ASR61 is placed immediately following the solenoids and has a direct view of Target E through its large aperture. Because of the expected radiation levels, the coils were also made using the indirectly cooled mineral insulated cable coil system and they were also manufactured by the Budker Institute in Russia. The extended pole is fitted with entrance and exit angle for focussing purposes. See Figs. 11, 12 and 13.

Fig. 11: ASR61 during the measurement process. The extended trapezoidal poles and the radiation hard coils can be seen. The two yoke pieces were made from the pole plates of a scrapped spectrometer magnet.

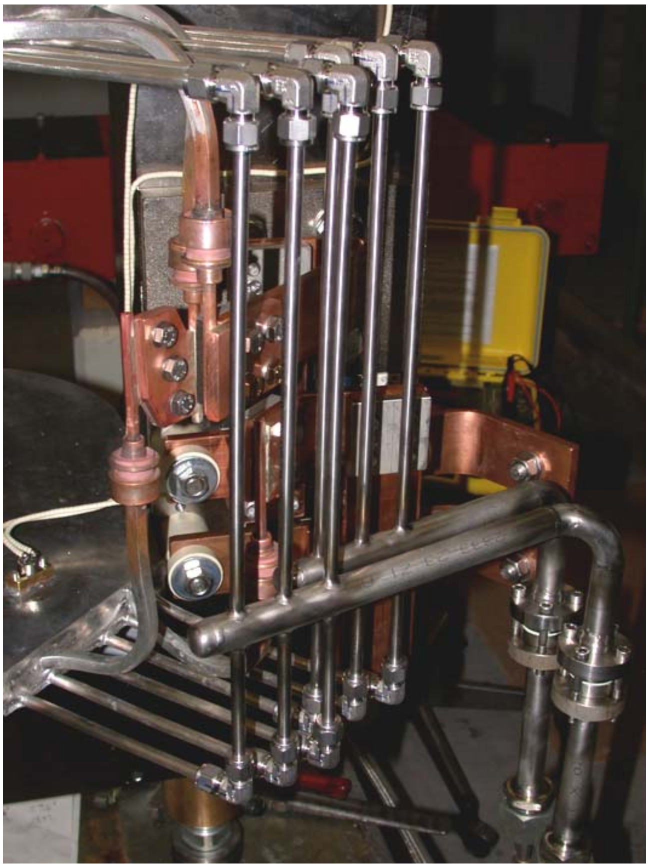

Fig. 12: The ASR61 electric and cooling connections, made in a very limited space. One can also see a thermoswitch with its connecting wires. They are insulated using hundreds of ceramic beads.

Fig. 13: The completed ASR61 with vacuum chamber ready for installation. All insulating components are made of ceramic due to the expected high radiation level.

The vacuum chamber of the second dipole ASR62 has an integrated beam stopper, which is operated through holes in both side yokes. As for ASR63, no edge angles were required, but magnetic shims were added during the measurement process to improve the magnetic field homogeneity. See Figs. 14 and 15.

Fig. 16 shows the completed ASR63, the yoke of which was manufactured locally using commercially available steel. The ASR62 and ASR63 conventional glass-epoxy insulated coils were manufactured by Sigmaphi in Vannes, France.

Fig. 14: ASR62 during the measurement process. The extended straight poles, the conventional glass-epoxy insulated coils and the holes for the special vacuum chamber in the side yokes can be seen.

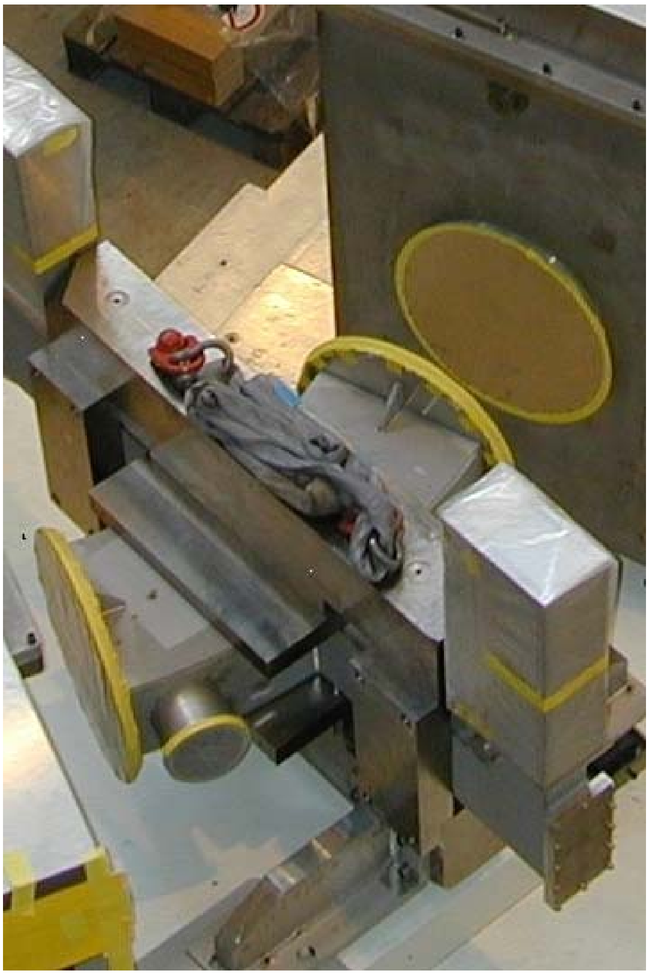

Fig. 15: The bending magnet ASR62 installed on the LEM trolley. The vacuum chamber side extensions for the movement mechanism of the integrated beam stopper passes through the side yokes of the magnet.

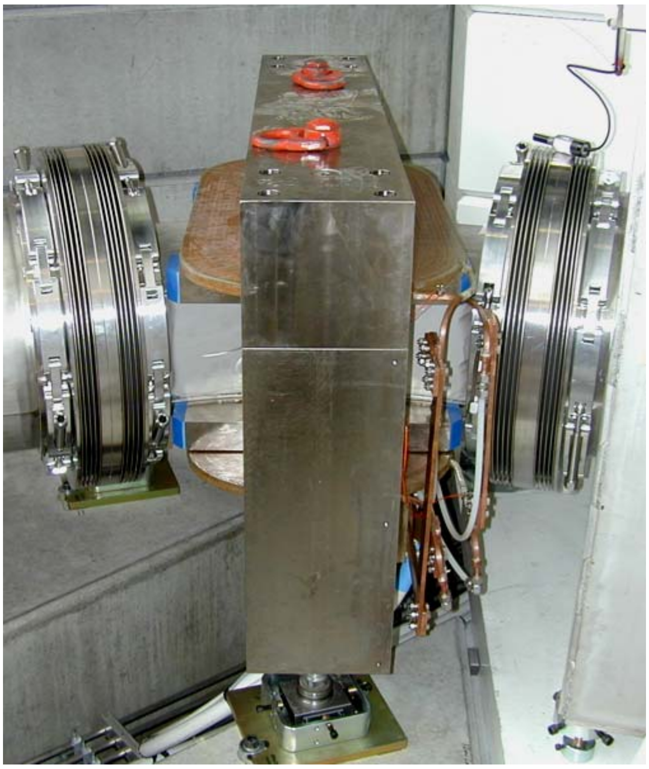

Fig. 16: The bending magnet ASR63 installed in the new μE4 beam line (LEM beam line).

GENERAL

In order to provide an overview of all the various magnets, a schematic diagram of the new μE4 beam line (LEM beam line) is shown in Fig. 17.

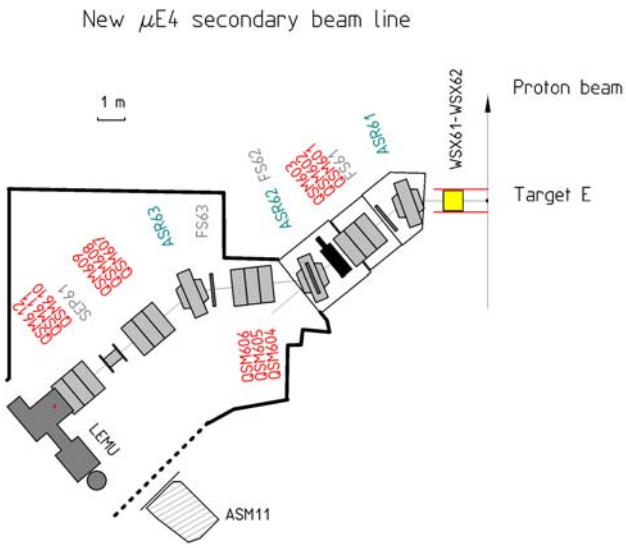

Fig. 17: Layout of the new μE4 beam line. LEMU is the attached experimental apparatus. ASM11 belongs to the neighbouring experimental area.