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MASTER

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80" Chamber - Low Energy Beams

One of the major, as well as first, decisions which must be taken on a large chamber is to decide on the direction of the magnetic field, i.e., vertical or horizontal. Either alternative has advantages and disadvantages and it is the intention of this note to discuss these features.

Consider first the case of a vertical magnetic field. This is in fact the usual direction for fields in beam bending magnets, since such fields change the direction of beams in the horizontal plane, and consequently the vertical height of the beam remains fixed. For the situation of low energy beams which stop inside the bubble chamber the vertical field is an advantage. The fringing field of the magnet as well as the field over the bubble chamber will bend these low energy particles considerably in the horizontal plane. The bubble chamber must be rotated around a vertical axis to produce the correct entrance angle into the chamber so that these low energy particles do in fact stop in a useful place in the chamber. This is of course simple and easily accomplished and in principle presents no problem for low or high energy beams.

The vertical magnetic field requires the window or windows of the chamber to be horizontal. For retrodirective illumination systems it requires also that the retrodirective elements are horizontal and at the bottom of the chamber. Two basic disadvantages arise from this geometry. The first has to do with the upper window. Bubbles which form during expansion rise to this window carrying heat to it. If the window is kept absolutely horizontal then automatically this window becomes warmer than the liquid because of these bubbles and because of the low conductivity of the glass. Consequently the window is usually tipped to allow the bubbles to move upward along the glass and to accumulate at a metal surface which can adequately handle this heat load by virtue of its high conductivity. The tipped glass also helps the reflection problems which are inherent in the retrodirective system.. For straight through illumination it is an added complication. However the horizontal, or tipped horizontal, glass remains a problem in the temperature control of the chamber because of its inherent poor conductivity.

The second disadvantage of the vertical field configuration is the bottom surface of the chamber. If retrodirective illumination is used it is extremely likely that dirt and other solid material will, in time, coat the optical surface and thereby lower the contrast of the photographs because of light scattering. Careful cleaning of the bubble chamber and careful filtering of the hydrogen may help this problem, but it may be a difficult problem to solve completely. The same can be said for a chamber using straight through illumination, since the lower window will become the deposit surface for all dirt and solids. In the case of the vertical field the important disadvantages have to do with the quality of photography and the temperature conditions of the chamber. Both are extremely important if the chamber is to be designed as an instrument for high quality precision measurements. A major advantage is the ease with which beams of all energies, including stopping beams can be guided into the chamber.

For a horizontal field the situation is exactly reversed. In this case the windows or retrodirective elements are vertical and the top of the chamber is a metal surface. All dirt or solids now fall to the bottom of the chamber and do not cause deterioration in the contrast of the photographs. Furthermore the rising bubbles contact a metal surface and create no heat problems. The top and bottom surfaces, being metal, are available for creating the desired horizontal temperature boundaries. Consequently the configuration has decided advantages from the point of view of producing precision measurements.

The important disadvantage is related to slow beams of particles which are to stop in the chamber. The horizontal magnetic field deflects particles in a vertical plane and the fringing fields cause these particles to undergo large deflections before entering the chamber. In order to understand the beam problems associated with the horizontal field magnet extensive trajectory plots have been made.

Figure 1 shows the preliminary pertinent dimensions of the 80" chamber and magnet. This is a section perpendicular to the magnetic field and in the vertical symmetry plane. The chamber has a clear front glass area 25" wide by 80" long, the ends being half circles of 25" diameter. The depth of the chamber is 20". The beam entrance window in the chamber body will be approximately 12" deep by 20" high. For the trajectory calculations the field has been assumed constant over the entire chamber body. From the chamber body outward to the edge of the coils the field has been assumed to fall off linearly with the distance along the median horizontal plane. Outside of the coils the field has been considered negligibly small. The above assumptions coincide reasonably well with measurements which have been made on the 20" chamber magnet and on a 1/5 scale model of the 20" magnet. The configuration of the 80" magnet is similar to both of these smaller magnets. The trajectories in the hydrogen of particles which stop by ionization loss have been calculated by J. Sandweiss using data contained in UCRL Report #2426 Volume II. These computations were made on an IBM 650 at Yale University. The remainder of each trajectory, outside of the liquid hydrogen, was computed by J. Sanford using the LGP-30 at Brookhaven.

It is clear that the smaller the mass of the stopping particle, the more difficult will be the problem of getting a beam of given momentum into the chamber. The lightest particle which will be of importance for experiments involving decay or interaction at rest is the K-meson . Figure 1 shows K-mesons coming to rest in the chamber, when the magnetic field is 15,000 gauss. These K-mesons enter the magnet with a momentum of 450 Mev/c. At the vacuum tank wall they pass through 5 grams/cm^2 of steel and at the chamber wall they traverse 32.2 grams/cm^2, part of which is steel wall and part additional absorber. The relatively thick absorber is important since it allows higher momentum K-mesons to be used. This reduces decays in flight and also reduces bending in the stray field. The K-mesons have 260 Mev/c momentum upon entering the liquid hydrogen. The two trajectories drawn indicate the upper and lower boundaries of a 4" high beam. The central trajectory (not drawn in) was chosen so that the K-meson would stop near the central horizontal plane of the chamber and equidistant from the near end of the chamber and the upper and lower edges of the glass. Except for the long dimension toward the right end of the chamber this will give equal track lengths to the boundaries. The important point with these trajectories is the angle at which they must enter the coil region, namely 22° with respect to the horizontal. We call this the attack angle. In order to obtain large attack angles an auxiliary magnet is necessary. This auxiliary magnet is shown in place in Figure 1. In addition, the central horizontal plane of the main magnet must be raised approximately 12" above the beam height. Thus with the auxiliary magnet* and appropriate jacking facilities it is possible to use K-meson beams which stop in the liquid hydrogen of the chamber.

Figure 2 shows the same 450 Mev/c K-meson beam entering the chamber, but with a 10,000 gauss field. In this case the attack angle is only 8° and consequently the situation is more favorable than that shown in Figure 1. For stopping K-mesons a lower field would be satisfactory since secondary particles which result from the K interaction at rest have very low momenta. This is also true for decay products of these secondaries.

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* The auxiliary magnet would have poles approximately 10" x 24" with a 6" gap and a field of 12,000 - 15,000 gauss. The main magnet iron could serve as part of the return path for this magnet. In this case the auxiliary magnet would weigh approximately 5 tons and use about 50 kilowatts maximum.

It should be pointed out that if stopping particles are desired which traverse longer path lengths in the liquid hydrogen, then the attack angle becomes larger. If one wishes to perform an experiment on the resulting interaction of stopped K-mesons and protons or neutrons then the longer path length is unnecessary. If one wishes to investigate the the interactions in flight of slow K-mesons then the longer path length would be useful.

Another consideration, with K-beams, is how they will be produced. The 80" chamber will be used at the AGS machine. With this machine the best K-beams will be produced from internal targets. This follows from the fact that the circulating proton beam will be able to traverse thin targets many times, yet maintaining a stable beam. This is important since it gives a small source size which is crucial for beam separation techniques. It also allows a large fraction of the proton beam to interact with the target. Under these conditions the bubble chamber should be relatively near the target (100-200 feet). However the 80" chamber will be 400 to 500 feet from the target and consequently a very large fraction of the K's will decay. It is quite likely that smaller chambers, such as the BNL 20" or the Columbia 30" will be more useful for investigating low momentum K-meson beams at the AGS.

Figure 3 shows a beam of 510 Mev/c antiprotons. Since anti-protons have such a large interaction cross section the beam entrance windows must be kept thin. In Figure 3 5 grams/cm^2 have been used for the vacuum tank and chamber beam windows. The particles enter the liquid hydrogen with 410 Mev/c momentum. The field in the chamber is 15,000 gauss and the attack angle is 17°. Again the auxiliary magnet is needed. Due to the fact that the anti-protons are heavier than K-mesons the trajectories are less curved in the chamber and it is obviously easier to deal with anti-proton beams.

One very important function of the 80" hydrogen chamber will be to act both as a target and an analyzer. In this case energetic particles will enter the chamber interact and produce secondaries. Long path lengths of hydrogen will be important under these conditions. Figure 4 illustrates trajectories of particles having 750 Mev/c, 1 Bev/c and 3 Bev/c momenta. The magnetic field is 15,000 gauss. Figure 4 draws attention to the elementary fact that even high momentum particles are deflected a large amount in a long chamber having a large magnetic field. If maximum path lengths in hydrogen are desired, then with particles having momenta less than 2 Bev/c the auxiliary magnet will be useful.

The horizontal magnetic field configuration has important advantages with respect to the optical and temperature conditions of the chamber. The major disadvantage is the necessity of a small auxiliary magnet to produce the correct attack angle for low energy or stopping beams.