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LARGE MAGNET SPECTROMETERS FOR ISABELLE

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LARGE MAGNET SPECTROMETER FOR ISABELLE.

Buried in a previous note (CRISP 71-31) was a brief description of a large magnet spectrometer. The present note is an elaboration.

(1) Introduction.

Experiments at ISABELLE will present unique problems for which there is almost no experience to draw upon. Present theoretical models predict particle multiplicities or spectra, but little guidance is available if one wants to look past experiments that measure those quantities. One rather obvious possibility is to look for particle correlations in the fragmentation region. Recent experiments on resonances indicate that some cross sections may stay almost constant at high energies and that production occurs near $t=0$. It seems reasonable to study these processes at ISABELLE energies.

(2) Kinematics.

The experiments we have in mind are of the type $p+p \rightarrow X + \dots$. X would consist of n particles. It could be, for example, a N^* or a boson. These high mass hadrons are produced at angles close to the beam direction because of the expected exponential t dependence.

The apparatus measures the momenta p_i and angles θ_i of n particles the effective mass of which is

$$(1) \quad M_X^2 = (\sum E_i)^2 - (\sum \vec{p}_i)^2.$$

As a guide in understanding the kinematics it is profitable to study the two body decay of X . Then

$$(2) \quad M_X^2 \approx p_1 p_2 \theta^2$$

where θ is the angle between the decay products.

Also

$$(3) \quad \frac{\delta M_X}{M_X} \approx \sqrt{\frac{1}{4} \left[\left(\frac{\delta p_1}{p_1} \right)^2 + \left(\frac{\delta p_2}{p_2} \right)^2 \right] + \left(\frac{\delta \theta}{\theta} \right)^2}.$$

Inspection of (2) indicates that the mass acceptance of a spectrometer scales as M_X/E where E is the energy of X , and our present knowledge of resonant states suggests aiming for a maximum value $M_X/E = 0.05$, i.e. $M_X \leq 10$ GeV. This determines the size of the spectrometer as further discussed in the next section.

The mass resolution is dominated by the momentum resolution in the spectrometer. A 15 kG field gives $\Delta p/p = 222m$ for 100 GeV particles. With spark chamber accuracy 10^{-4} m, spark chamber separation 2m, and field length 2m, it is possible to achieve

$\Delta p/p, \approx 1\%$. Hence $\Delta M_X \approx 50$ MeV for $M_X = 7.5$ GeV can be obtained without difficulty.

(3) Apparatus.

The considerations discussed above suggest a spectrometer as indicated in fig. 1. The colliding beams pass through the center of a magnet of opening $2m \times 1.5m$ and $\int B dl = 56$ kGm. The magnet center is approximately 5 m from the interaction region. n particles originating at a vertex in the interaction region pass through the walls of a scattering chamber designed to minimize multiple scattering. Their tracks are recorded before and after passage through the magnet and a threshold Gorenkov counter hodoscope.

The acceptance for X decaying into n particles can be inferred from fig. 2. (Fig. 2 is a phase space calculation for the process $X \rightarrow n$ pions and $E = 80$ GeV. It should be kept in mind that the acceptance scales as M_X/E). Typically, for $M_X/E = .05$ and the decay $M_X \rightarrow 3\pi$, the detection efficiency is $\sim 50\%$; for each additional pion the acceptance decreases by approx. 15%. It is therefore essential to place the magnet as close as possible to the interaction region, providing however, adequate distance to obtain satisfactory momentum resolution.

The performance of the C-counter hodoscope depends strongly on a careful design. Extrapolation from threshold counter performance at Serpukhov (ref. S. Kruss, 1970 NAL Summer Study) indicates that such a counter of 10m length would have a pion efficiency of 94% at 100 GeV when set to just reject kaons. In a hodoscope the light collection would not be expected to be as good, and the efficiency consequently would drop rapidly. For instance, if the efficiency for light collection were $\frac{1}{2}$ that of the Serpukhov counters the π efficiency would drop to 50%.

Actually, few particles would be expected to have energies near or above 100 GeV. It might be more reasonable to set the counter to have a pion threshold of 10 or 20 GeV. For a pion threshold of 20 GeV and 50% Serpukhov efficiency, for instance, π at 30 BeV could be collected with 75% efficiency, and for π above 50 BEV the efficiency would be $\geq 90\%$. The K threshold would be at 71 BeV and the proton threshold would be at 132 BeV.

(4) Requirements of INSTALL.

- (a) Beams pass through high magnetic field. Compensation will be necessary.
- (b) Special vacuum chamber near interaction region to minimize multiple scattering of particles originating in the interaction region.

- (c) As outlined earlier (CRISP 71-31) it would be highly desirable to have the two beams operate at independent energies. By use of the forward motion of the center of mass for unequal colliding beams the effective ratio M_x/E can be decreased by up to a factor 3. This means a very drastic increase in efficiency for multiparticle production, corresponding to an increase in the magnet opening by a factor 9. This feature will also permit shifting a given θ in the center of mass to different regions in the laboratory. Hence θ_{lab} regions inaccessible because of vacuum enclosures, etc. will not restrict exploration of all center of mass angles. Furthermore, this flexibility will permit extremely valuable consistency checks for all experiments.

(5) Acknowledgements.

Many aspects of the spectrometer described in this note are similar to the one described in experimental proposal #110 for NAL by a collaboration from California Institute of Technology, National Accelerator Laboratory, Northeastern University at Boston, SUNY at Stony Brook, University of California at Los Angeles, University of Illinois at Chicago Circle. Some details, especially figure 2, are lifted directly from that proposal, and thanks are due all the authors of that paper.

FIG 1. LARGE APERTURE MAGNET SPECTROMETER.

Figure 2. Spectrometer acceptance at 80 GeV/c vs n in $\pi^0 \rightarrow (n\pi)^0$ for fixed mass m_π . (For 1.5 and 5.0 meter target-magnet separation.)