EARLY RESULTS
FROM THE JETSET EXPERIMENT

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ABSTRACT

The JETSET experiment at CERN-LEAR was commissioned in 1990. The aim of this experiment is to search for hadronic resonances by probing exclusive gluon-rich reactions of the type $\bar{p}p \rightarrow \phi\phi$ and complementary channels. The total and differential cross sections and the spin observables of the decaying ϕ mesons are measured versus incoming antiproton momentum. A center-of-mass energy range for this reaction from 2.04 to 2.43 GeV is accessible at LEAR. Nine energy bins clustered toward the higher end of the range have now been roughly measured. A preliminary analysis of a portion of the data is described. The most important conclusion is that the reaction $\bar{p}p \rightarrow \phi\phi$ is clearly and cleanly seen.

INTRODUCTION

The ϕ meson is a particularly attractive particle for probing gluonic interactions. Production of the ϕ is expected to occur through an OZI-forbidden mechanism since its composition is almost purely $s\bar{s}$. The narrow width of the ϕ (4.4 MeV) and its signature two-kaon decay mode imply that a straight-forward detection algorithm can be devised. Production of $\phi\phi$ pairs in hadronic channels and in radiative J/ψ decays has revealed structure in the mass range from threshold to about 2.5 GeV. In the former, a $\pi^- p \rightarrow \phi\phi n$ experiment at BNL has led to the claim of three $J^{PC} = 2^{++}$ resonances[1] which are interpreted by the authors to be tensor glueball states. These were originally called

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$g_T(2100)$, $g_{T'}(2200)$, and $g_{T''}(2450)$ but are now officially termed "f_2" by the Particle Data Group. An interesting feature of the BNL results is the large signal-to-noise ratio of the $\phi\phi$ events compared to non-resonant multi-kaon backgrounds. The authors deduce their glueball interpretation based, in part, on the belief that this signal-to-noise indicates a breakdown of the OZI rule as expected for a purely gluonic intermediate state. In the $J/\Psi \rightarrow \gamma\phi\phi$ experiments, where all decays are OZI forbidden, a $J^P = 0^-$ structure at 2.2 GeV is seen.[2,3] Here, no hint of the tensor resonances is observed.

The JETSET experiment will attempt to shed light on this and other spectroscopy problems in the mass range above $2m_p$ by using $\bar{p}p$ in-flight annihilation into selected two-meson final states. The primary initial interest is the channel $\bar{p}p \rightarrow \phi\phi$. Production of a $\phi\phi$ pair might proceed by coherent annihilation of the incoming non-strange quarks and antiquarks, followed by formation of two $s\bar{s}$ quark pairs which materialize as ϕ mesons. The ϕ mesons can then immediately decay to four kaons. Highest sensitivity to gluonic resonances occurs if this gluon-mediated production mechanism dominates over competing processes which involve $s\bar{s}$ production from the sea quarks, or $\phi\phi$ production through an ω–ϕ mixing process. The latter two processes are OZI allowed.

The experiment is relatively simple in concept. Exclusive four-charged-kaon events must be detected following a $\bar{p}p$ annihilation at a variety of incoming antiproton momenta (ie., $\sqrt{s}$). Unique kaon identification among the multitude of four-charged-particle background channels (including higher multiplicity channels with undetected components) is the first obstacle. This, however, is under the experimentalist's control. The second obstacle is controlled by nature and involves the ratio of $\bar{p}p \rightarrow \phi\phi \rightarrow 4K^\pm$ events to those events coming from either direct or semi-direct four-kaon processes such as $\bar{p}p \rightarrow 4K^\pm$ or $\bar{p}p \rightarrow \phi K^+K^- \rightarrow 4K^\pm$. The only guide to this ratio in our energy region comes from six bubble chamber events of the type $\bar{p}p \rightarrow 4K^\pm$ measured by Davidson et al.[4] Of these, one is consistent with a $\phi\phi$ intermediate state; the estimated cross section is 600 nb. A further hint of the $\bar{p}p \rightarrow \phi\phi \rightarrow 4K^\pm$ cross section is given by Baglin et al.[5] from the R704 jet-target experiment in the ISR. In the center-of-mass energy range corresponding to the η_c mass, a 25 nb cross section is seen. The JETSET experiment is designed to confront such low cross sections as explained below. In the preliminary analyses of the initial physics runs, we see that the apparatus functions properly, yielding a reliable sample of exclusive $4K^\pm$ events. Moreover, a very strong $\phi\phi$ signal is seen which indicates that the ratio discussed above is not small. This is important since we use the $\phi\phi$ events to look for possible resonance behavior in the intermediate (gluon-rich) state.

THE EXPERIMENT

The JETSET experiment at the CERN Low-Energy Antiproton Ring (LEAR) is primarily designed to observe events of the type $\bar{p}p \rightarrow 4K^{\pm}$ in an energy region where the kaons are relatively slow. High luminosities are required due to the low expected cross section. To achieve this, the experiment utilizes the jet-target technique in which the coasting antiproton beam is continuously crossing a dense hydrogen-cluster jet target in the middle of one of the ring's straight sections. Luminosities above $10^{30}cm^{-2}s^{-1}$ are projected for our setup with the additional feature that the interaction volume is relatively small, $< 1\ cm^3$. Accordingly, the detector is built around the intersecting beam and jet vacuum pipes and is compact in design. The complete device includes subcomponents which perform the three classic tasks: triggering, tracking, and particle identification (PID). A plan view is shown in Figure 1. Note that no magnetic field is present.

The triggering scheme is based on detection of four charged particles in the forward hemisphere of the experiment with nothing else behind. If the particles are kaons, they will be relatively slow compared to the plethora of pions from background channels. A total of 60 scintillator strips surround the LEAR beam pipe just downstream of the jet. They are grouped, like the rest of the detector, into "forward" and "barrel" units. The strips define polar angular corridors of 15°-45° and 45°-65° and are segmented azimuthally into 40 or 20 strips, respectively, to provide an accurate multiplicity count. Particles which pass through these counters will enter downstream tracking and PID detectors. A total multiplicity of four charged particles is required at the first level trigger, with the additional selection that at least three of the four particles enter the forward (15°-45°) region. Segmented threshold Cherenkov counters filled with either water ($\beta_{thres}= 0.75$) or freon ($\beta_{thres}= 0.80$) are required to have no more than one or two hits. This condition depends on the incident antiproton energy since the choice of energy influences the range of speeds of the outgoing kaons. In concept, slow kaons are ignored and fast pions are rejected.

Further particle identification may be accomplished in the offline analysis by testing the compatibility of the Cherenkov counters and by using the large array of silicon pad detectors whose function is to provide dE/dx information. Two such energy measurements are made per particle on those particles which pass through the forward region of the detector. A gamma detection system, consisting of a 300-element, high-resolution electromagnetic calorimeter in the forward region and an array of 24 longitudinal bars in the barrel region is used to identify and reject events with neutral components, primarily from π^0 decay.

Charged-particle tracking chambers consisting of aluminum "straw" drift tubes are placed just outside and downstream of the beam-pipe scintillators. In the forward region, $\approx$ 1000 straws are arranged in two horizontal and two vertical planes. In the barrel region, an additional 1500 straws are placed as a dense pack surrounding the beam and straddling the jet with their axes aligned along that of the beam. For the barrel tracker only, charge division is used to provide a third coordinate along the beam-line direction thereby producing three-dimensional space points from recorded hits. To complement the chamber tracking, both the silicon pads and the forward calorimeter towers may be used to point to potential tracking roads. Finally, one multipurpose detector consisting of three layers of segmented plastic scintillator strips exists in the outer region of the detector in both the forward and barrel sectors. The layers are arranged to provide crossing angles that define unique pixels. The pixels may be used in the track finding road-search algorithm. Pulse-height information in the scintillators may also be used to form additional dE/dx tagging and finally, the segmented planes are used for multiplicity selection in the first-level trigger.

FIRST PHYSICS RUNS

The experiment was mounted in the Fall of 1990 and Winter of 1991. Short pilot runs in December of 1990 and April of 1991 preceded the first "physics production run" in July of this year. Another run is scheduled for October 1991. During this initial phase of the experiment, a complete scan from below $\phi\phi$ threshold to the highest LEAR momentum (2.0 GeV/c) is planned. The combined April and July data inclusively spanned the momentum range 1.2 to 2.0 GeV/c in steps of 0.1 GeV/c corresponding to a center-of-mass range of 2.15 to 2.43 GeV. The typical antiproton intensity stored in LEAR at the beginning of a coast was 2.0×10^{10} particles, each with a circulating frequency of approximately 3 MHz. This coupled with an effective gas jet density of typically 5×10^{12} atoms/cm^2 yields a working luminosity of just above 3×10^{29}cm^{-2}s^{-1}. This number is expected to rise as the LEAR intensity is raised and as adjustments in the gas-jet system are made. Note that the source of the jet is a full 1.1 m from the interaction region, thus the relatively low density compared with alternate arrangements. Nevertheless, even at the start, this luminosity figure represents a near maximum compared to any similar extracted-beam experiment at LEAR. The integrated luminosity for each of the energy points measured in the April and July runs is in the range of 20 - 40 nb^{-1}. All of these numbers are preliminary, obtained at this stage only from observations of the rate of decay of the stored antiproton intensity. A $\bar{p}p$ elastic scattering trigger is acquired in parallel to the main triggers and will be used for more precise normalization.

The high and low ends of the momentum range introduce separate experimental difficulties. At the lowest momenta, the kaons from ϕ decay are very slow. They tend to decay or even stop in the apparatus which makes up or supports the inner components of the full detector. At the highest momenta, where the kaons are considerably faster, the condition on the threshold Cherenkov counters must be loosened since up to two of the four kaons can have a beta above threshold. Additionally, the background channel $\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$ opens up with a cross section which rises steeply to dwarf the expected $\phi\phi$ cross section by several orders of magnitude at the highest energy. This channel can mimic the outlined $\phi\phi$ trigger. Many tools exist in the offline evaluation which essentially eliminate this contaminant, however, algorithms are continuing to be developed at this early stage in the data processing.

PRELIMINARY RESULTS ON THE $\phi\phi$ SEARCH

For the initial inspection of the data, only events with four clean tracks are studied. No gammas are permitted to fire the barrel gamma detectors and the other trigger counters are required to operate in a fully efficient manner. A sample of 4-track events, which additionally has the proper azimuthal balance and Cherenkov counter response, is subjected to a kinematic evaluation for each combination of the pairs of kaons. There are 16 unknowns in the final state which describe the 4-vectors for each particle. Four conditions are given by the well-defined initial $\bar{p}p$ state and eight are given by the polar and azimuthal angles of the charged tracks. The four remaining quantities are the *assumed* masses of the particles; these are assigned to that of the kaon. From these conditions, a set of solutions can be made for the individual momenta of the kaons. In total, either three or six solutions are legal, the reduction from six to three occurs when compatibility requirements based on the energy loss in the silicon pads and in the scintillator strips and in the firing or non-firing of the Cherenkov counters are incorporated to restrict the ranges of inferred kaon momenta. From the solutions, effective mass combinations from pairs of kaons are made. These effective masses are displayed on a Goldhaber plot of $M(K_i K_j)$ versus $M(K_k K_l)$ where it should be again noted that either three or six entries per event are made. Recall, there is no magnetic field to identify even the sign of the kaons.

For a given antiproton momentum, the limits of the Goldhaber plot are given purely by the kinematics and form a triangular shape. In a world of pure $\phi\phi$ events, a Goldhaber plot of these events would show a concentration at the crossing of the ϕ mass on each axis *and* a wrong-combinations band close to the hypotenuse of the triangle. For a sample of purely non-resonant $\bar{p}p \rightarrow 4K^{\pm}$ events, the triangle would be uniformly filled with no enhanced structures or bands. The Goldhaber plot shown in Figure 2 is obtained from the July 1.4 GeV/c data. A clear structure at the $\phi\phi$ mass is visible. The background, which represents non-kaon events which have leaked into the sample and kaon events from the competing physical processes $\bar{p}p \rightarrow 4K^{\pm}$ and $\bar{p}p \rightarrow \phi K^{+}K^{-} \rightarrow 4K^{\pm}$, clearly does not dominate the landscape. The $\phi\phi$ signal is also observed at other energies, however at this early stage in the analysis, nothing conclusive can be stated about the actual composition of the individual Goldhaber plots. At this point, we have certainly missed some fraction of the true $4K^{\pm}$ events and we have included into the plot some unknown fraction of background channels. Moreover, the efficiency of both our detector and our analysis chain is energy dependent; these issues are being studied carefully now. Nevertheless, we note that the primary probe we have into the gluonic world, namely the $\bar{p}p \rightarrow \phi\phi$ cross section versus energy, is an attractive one which has the capacity to bear meaningful fruit. The $\phi\phi$ events stand out cleanly from the aggregate background. Therefore, the results from the more detailed observables such as the differential cross section and the angular parameters associated with the ϕ decay will be more informative. At this stage, a very satisfactory step has been taken.

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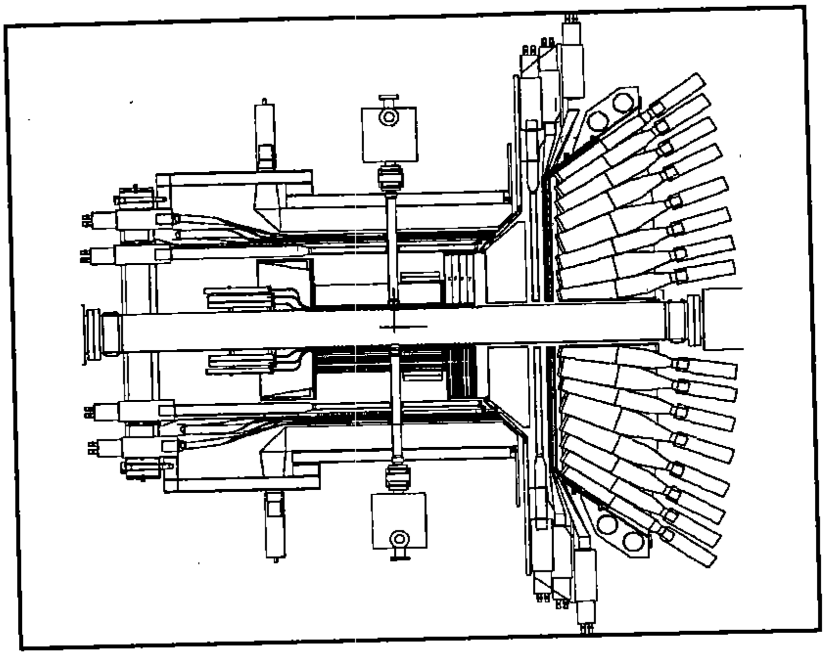

Figure 1. Plan view of the JETSET apparatus.

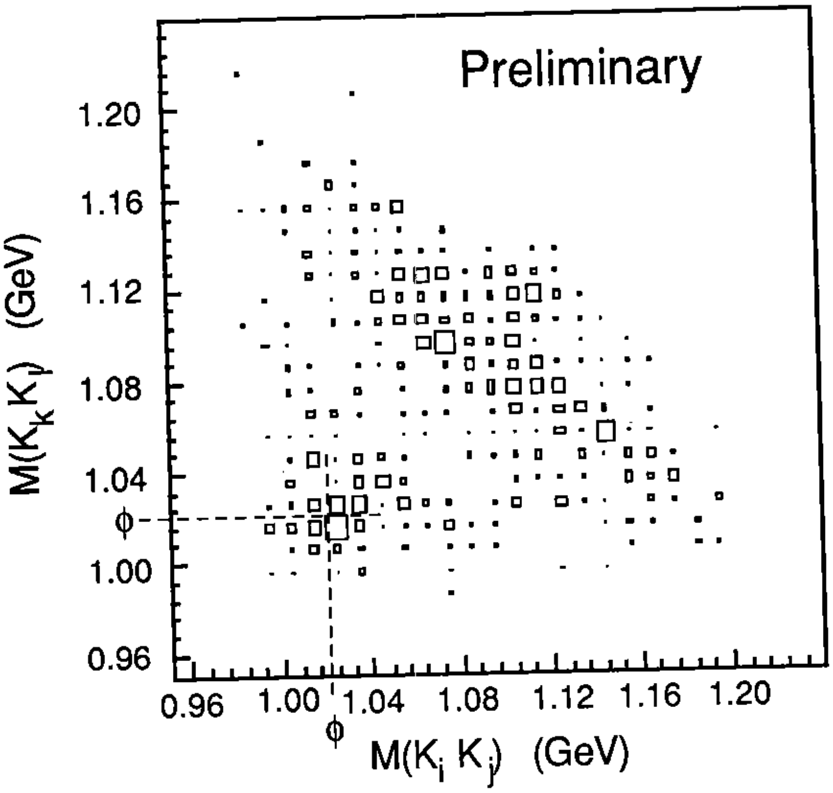

Figure 2. Goldhaber plot of bidimensional invariant mass combinations from kaon pairs. This result is preliminary from data obtained at an incident antiproton momentum of 1.4 GeV/c corresponding to $\sqrt{s}$ = 2.22 GeV.