CHARMONIUM AND DIRECT PHOTON PRODUCTION FROM FERMILAB E-705

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Abstract
Several aspects of QCD are to be investigated by E-705, a Fermilab experiment set-up to measure the hadronic production of charmonium chi states and the direct production of photons with high transverse momentum. The physics motivation, the apparatus and data taking parameters are described and preliminary results from the analysis are presented.

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The E-705 spectrometer.

The Fermilab High Intensity Area Spectrometer, installed on the Proton-West beam line, was utilised during the 1987/88 Fixed Target run to collect data on the hadronic production of charmonium χ states as well as of photon directly produced with high transverse momentum. As shown in fig.1, the spectrometer consisted of a 32.9 cm (0.24 interaction lenghts for protons) Lithium target, a tracking system, an analysis magnet, an electro-magnetic calorimeter and a muon detector. The tracking system included proportional and drift chambers, for a total of 19 planes in front of and 12 behind the magnet. All the chamber were desensitised in a central region around the beam, but for part of the run an additional set of 9 proportional planes with fine wire spacing was employed to record tracks produced at a small angle with the beam.

The electro-magnetic calorimeter [1] represented a very crucial element of the apparatus, since both the χ and the direct photon measurements require a good determination of photon energy and position. It consisted of two sections,an "active converter", 3.5 radiation lenghts thick, where electro-magnetic showers would be initiated and the centroid of the shower determined, and a "main array" where the whole shower would be contained. The active converter consisted of a sandwich of lead and proportional tubes in the central region, and of bars of scintillating glass, followed by two planes of proportional tubes, in the wings [2]. The main array was a stack of scintillating glass and lead glass blocks of two different sizes, 7.5x7.5 cm^2 in the central region and 15x15 cm^2 in the outside of the stack. The scintillating glass, a new material for which our setup represents the first application in a High Energy Physics experiment, was chosen because of its higher light yield when compared with traditional lead glass -about a factor of 5- as well as for its much higher (about 100 times) resistance to radiation damage [3]. The stability of the photomultipliers viewing the glass blocks was monitored by pulsing a bundle of green LED's whose light was distributed to each block by means of fiber optics. The absolute calibration of the array was determined periodically by positioning each calorimeter element in the path of an electron beam transported into the experimental area. The calibration was performed at different energies, ranging from 2 to 100 GeV.

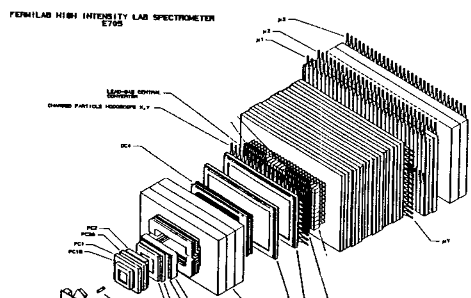

Fig. 1 : The E-705 spectrometer.

The muon detector consisted of four planes of scintillation counters **inserted** into three gaps of a massive steel and concrete hadron absorber. The thickness of the absorber was such as to range out muons with less then 6 GeV/c incoming momentum, and a μ was defined as a triple coincidence of corresponding elements from the three planes of vertical counters.

The experiment took data with two major triggers, dimuon and high p_t photon, at interaction rates exceeding 10^6 interactions/sec. The dimuon trigger consisted of two stages: first the presence of two muons in two different quadrants was required; next, a hard-wired processor [4] would perform an online computation of the invariant mass of the dimuon system, rejecting low mass triggers, for an overall triggering rate of $1.4 \cdot 10^{-4}$/ interaction. The high p_t photon trigger was derived from a fast analog processor [5] which detected local maxima ("clusters") of energy deposition in the calorimeter by comparing each block with its neighbours. Next, the processor obtained the total energy of each cluster, converted it to transverse energy, and accepted the event if it was above a preset threshold. For a nominal threshold of 4.5 GeV, the processor was running at a rate of 10^{-5} triggers/interaction. Lower p_t events were also accepted, at rates suitably prescaled to limit Data Acquisition dead-time, by imposing three additional thresholds, nominally set at 1.7, 2.5 and 3.5 GeV.

The Data Acquisition system [6], consisting of intelligent CAMAC Controllers and a VME based Event Builder, was capable of standing a rate of 200 events/sec for a 20% dead-time. For a total number of $8 \cdot 10^{11}$ interactions in the target, the experiment logged about 200 million triggers onto more than 6000 tapes, running with both negative and positive beams at 300 GeV/c.

Hadroproduction of charmonium χ states.

The main objective of the experiment is a systematic study of the mechanism for the hadronic production of bound $c\bar{c}$ pair, performed through a measurement of total and differential cross-sections of the charmonium P-wave triplet ($\chi's$). Summarizing very briefly[7], it has been suggested that, within QCD, charmonium χ's should be produced more copiously than J/ψ's, since χ production can proceed from lower order diagrams than the J/ψ's. Such a prediction for "χ dominance" did not appear to receive full confirmation by the data (only 30% of J/ψ production by pions seems to derive[8] from primary χ's, so that alternative mechanisms were proposed. In order to throw light on the whole issue, it would be necessary to measure, with good statistics, total and differential (vs.x_F, p_t, decay angle) cross sections for **individually resolved** χ states, ideally with different incoming beams and at different energies, so that the elementary quark-quark and gluon-gluon subprocesses could be recognised and their relative importance quantified. As a specific example, χ_2 low p_t production by protons should be an almost pure two-gluon process, and its measurement would allow to perform a model independent determination of the gluon structure function. Experimentally, the measurement's biggest challenge is represented by the mass resolution one needs to achieve in order to separate the individual χ states. The mass separation of only 45 Mev between the χ_1 and χ_2 calls for a mass resolution of the order of 15 MeV or better, which in turn translates into few % and few mm accuracy for the measurement of photon's energy and position respectively. The E-705 electro- magnetic calorimeter was designed in an attempt to achieve such a performance; analysis of the calibration data recorded throughout the run shows that the intrinsic resolution of the system is in agreement with the early test results [3], and it can be represented by:

$$\sigma/E = 1.3\% + 1.8\%/\sqrt{E} + 4.8\%/E \text{ for the Scintillating Glass}$$

and

$$\sigma/E = 1.3\% + 5.0\%/\sqrt{E} + 5.0\%/E \text{ for the Lead Glass,}$$

the 1/E term being well explained by pedestal fluctuations. Such a resolution, when reproduced in the data, would be adequate to resolve the χ states. The analysis of the data, which is in progress, first isolates the ψ events from the sample of dimuon triggers (fig 2). Next the χ signal is looked for in the $\psi - \gamma$ invariant mass spectrum (fig. 3). The evidence for a peak at the right position is promising, even though more refined analysis is still needed in order to achieve the best resolution.

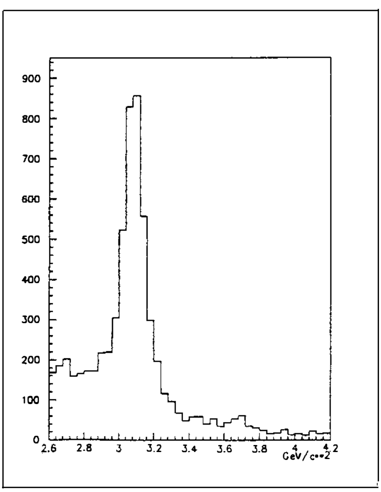

Fig. 2 : J/ψ mass spectrum, 20% of our data sample

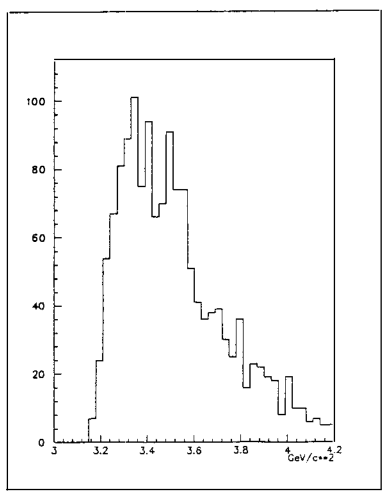

Fig. 3 : $\psi - \gamma$ invariant mass spectrum

Direct Photon Production

The direct production of photons with large transverse momentum, believed to proceed, at the lowest order, from the basic parton processes of quark-antiquark annihilation and quark gluon Compton scattering, has been the object of a large set of experimental and theoretical investigations[9]. Even so, there is still room for an improvement in the range covered by the existing data, as well as in its statistical and systematic precision. In this context, our experiment, with an integrated luminosity of about 7 $pbarn^{-1}$ for both π^+ and π^- induced events, should allow to perform the best comparison to date of the positive vs. negative pions direct photon signal. Good statistics data (6 $pbarn^{-1}$) will also be available for the proton beam, together with a smaller sample (.16 $pbarn^{-1}$) of antiproton induced events. The same electro-magnetic calorimeter described above plays the crucial role in the recognition of the direct photon signal. For such a measurement, the capability of resolving closely spaced showers, which allows to separate real photons from π^0's decaying with a small opening angle, is one of the most essential parameters. Our 30 GeV calibration data show that the hodoscopes imbedded in the calorimeter allow to recognize two showers as distinct if their separation is at least of 2 cm, corresponding to a 2 mrad opening angle. Similarly to the χ analysis, the photon analysis is also in progress: fig. 4 shows our current high p_t π^0 signal ($p_t > 3Gev/c$), while figure 5 is the π_0 cross section, inferred from a very small fraction (2%) of our data, and compared with the results from $WA70$[10].

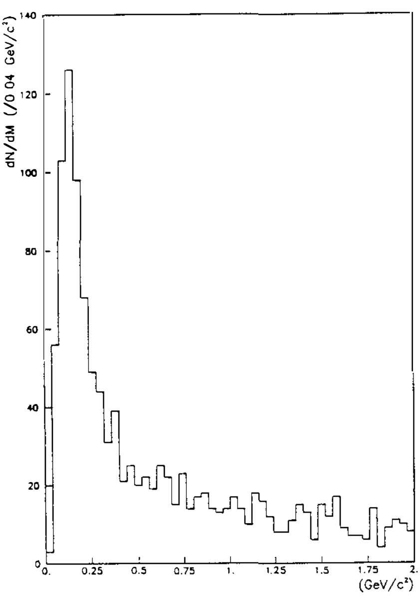

Fig. 4 : $\gamma - \gamma$ mass spectrum, 2% of our data sample.

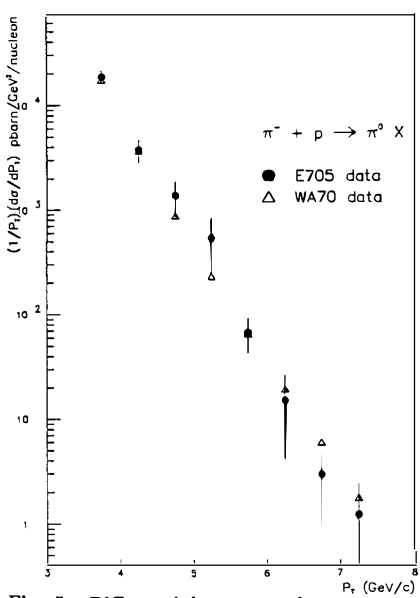

Fig. 5 : Differential cross section for high p_t π^0 production

REFERENCES

1- D.E. Wagoner et al., Proceedings of the Advanced Workshop on QCD Hard Hadronic Processes, St. Croix, Virgin Isl., Oct 8-13, 1987.
2- L. Spiegel et al., IEEE Trans. Nucl. Sc., NS-36, 86, Feb 1989.
C.M. Jenkins et al., IEEE Trans. Nucl. SC., NS-36, 117, Feb 1989.
3- D.E. Wagoner et al., Nucl. Instr. and Methods A238, 315, 1985.
B. Cox et al., Nucl. Instr. and Methods A238, 321, 1985.
4- H. Areti et al., Nucl. Instr. and Methods 212, 135, 1983.
5- G. Zioulas et al., IEEE Trans. Nucl. Sc., NS-36, 375, Feb 1989.
6- S. Conetti, Proceedings of the Conference on the Use of Microprocessors in High Energy Physics, ICTP Trieste, March 1988.
7- For a more comprehensive discussion of charmonium production and a detailed list of references, see S. Conetti, Proceedings of the Advanced Workshop on QCD Hard Hadronic Processes, St. Croix, Virgin Isl., Oct 8-13, 1987.
8- Y. Lemoigne et al., Phys. Lett. 113B, 508, 1982.
S.R. Hahn et al., Phys. Rev. D30, 671, 1984.
9- See the contribution by M. Werlen to these Proceedings.
10-M. Bonesini et al.,Zeit. Phys C37, 535, 1988.