

THE A-DEPENDENCE OF  $\psi$  PRODUCTION  
IN  $\pi^-$  NUCLEUS COLLISIONS AT 530 GeV/c

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ABSTRACT

The E672/E706 Spectrometer, located in the MW beam at Fermilab, was used to collect data on events containing a pair of muons in the final state with large effective mass. The momentum of incident pions and protons was 530 GeV/c. Nuclear targets included Be, C, Al, Cu and Pb. We report on a preliminary measurement of the A - dependence of the per nucleus cross section for forward  $J/\psi$  production. The apparatus also detected charged particles and  $\gamma$ 's produced in association with the muon pair. The expected physics results on the hadroproduction of  $\chi$  states and beauty particles are discussed.

1. Introduction

This paper summarizes recent results from Fermilab experiment E672, a fixed target experiment in the MW beam, the aim of which is to study hadronic processes yielding high mass dimuons (the trigger) and associated particles. The specific goals are:

- the characteristics of  $\psi$  production and Drell-Yan processes including A-dependence, multiplicities and momenta of associated particles

- the hadronic production of  $\chi \rightarrow \psi + \gamma$  states and associated particles
- BB production where one of the Bs decays into  $\psi + X$ , or where the semileptonic decays of both B and  $\bar{B}$  yield a  $\mu\mu$  pair with large invariant mass.

In this paper we concentrate on the effectiveness per nucleon of heavy targets in producing  $\psi$ 's. The effect is usually parameterized by the expression:  $\sigma(\text{hA} \rightarrow \psi + X) = \sigma_0 \times A^\alpha$ , with  $\alpha < 1$  implying a decreasing effectiveness of  $\psi$  production with increasing A of the nuclear target. This A - dependence has been studied by several experiments spanning the c.m. energy,  $\sqrt{s}$ , of 15 to 24 GeV (for this experiment  $\sqrt{s} = 31.4$  GeV). For the inclusive  $\psi$  production  $\alpha \simeq 1$ . However, for  $\psi$ 's produced at large  $x_f$  and with  $p_T < 1.2$  GeV/c the values of  $\alpha$  were found to be less than one<sup>1-6</sup>.

A number of mechanisms for the A-dependence of  $\psi$  production and nuclear suppression at large  $x_f$  have been proposed. At large  $\sqrt{s}$   $\psi$ 's  $x_f$  can be approximated as:  $x_f = x_1 - x_2$ , where  $x_1$  and  $x_2$  are fractions of the beam and target momenta, respectively, carried by interacting partons. Therefore, any mechanism which hardens the momentum distribution (suppression of the low x component) of target parton will decrease the probability of producing a  $\psi$  at large  $x_f$ . This observation rules out some mechanisms, as for example the EMC effect, which is described as a softening of the momentum distribution of target partons and would predict  $\alpha > 1$  at large  $x_f$ .

Since a large contribution of  $\psi$  production is expected to be due to gluon fusion<sup>7</sup>, any mechanism which affects the momentum distribution of target gluons would also influence the  $\psi$  production off nuclei. In particular the nucleons surrounding the target nucleon of a heavy nucleus could produce a "shadowing" effect by which the soft gluon component of the target is absorbed by the other nucleons, leaving a harder component intact<sup>8</sup>.

Another class of models explains the observed A-dependence of  $\psi$  production as due to the scattering of the beam particle before the  $\psi$  is produced or the scattering of the  $\psi$  itself before it escapes the nuclear target<sup>9</sup>. These effects decrease the number of  $\psi$ 's at large  $x_f$  and increase the average  $p_T$  of the  $\psi$ .

The E672 experiment took data during the Fermilab fixed target 1987/88 run. In this paper we present the experimental setup, trigger rates and preliminary results on the A - dependence of  $\psi$  production in  $\pi^-$  nucleus interaction at 530 GeV/c. We also discuss expected physics results on the hadroproduction of  $\chi$  states and beauty particles.

## 2. Apparatus

Experiment E672 studies dimuon production in an open-geometry configura-

ration. The experiment uses a dimuon detector consisting of a toroid magnet, proportional chambers, scintillator hodoscopes and a trigger processor. The E672 detector shares the MW beam line with E706 (see Fig. 1). The physics goal of E706 is a study of direct photon production. The E706 detector consists of a liquid argon calorimeter (LAC) and a spectrometer including a silicon strip detector (SSD; 14 x-y planes), 16 planes of PWC's and a forward calorimeter.<sup>10</sup> The two experiments take data simultaneously with the information from the entire apparatus being available to both groups.

The the E672 dimuon detector, located 21 m to 33 m downstream of the target, consists of:

- a PWC station (D) consisting of 3 planes
- a tungsten and steel beam dump
- a toroid providing an average  $p_T$  kick of 1.3 GeV/c
- four PWC chambers ( $\mu 1$  through  $\mu 4$ ), each with three planes
- two planes of scintillator, each with sixteen wedge-shaped counters
- associated electronics and pretrigger and trigger processors.

Signals from the scintillator planes are used to form the dimuon pretrigger (2 or more hits in each of the two planes). Data from the muon chambers are read via the LeCroy PCOS III system into a trigger processor<sup>11</sup> which: (a) finds space points at two of the chambers; (b) finds tracks; (c) computes momenta assuming the muons originated in the target and (d) calculates effective masses. The calculations of the momenta and masses take into account correction for the magnetic field in the dipole magnet. The mass resolution of the processor is set by multiple scattering to about 700 MeV. The average trigger formation time has been measured to be less than 10  $\mu$ s.

The pretrigger rate in the final configuration for  $\pi$ C interactions at 530 GeV/c is  $2 \times 10^{-4}$  interactions and is approximately four times higher than a genuine two muon tracks signal. The minimum energy required for muons to pass through the two pretrigger scintillator planes is 15 GeV. The trigger processor dimuon mass cutoff at 0.5 GeV reduces the trigger rate to  $4 \times 10^{-5}$  interactions.

### 3. The A - dependence for the forward $\psi$ production

During September 1987 data were taken with the E672 part of the apparatus only (no SSD or PWC data were available). The incident beam was 530 GeV/c  $\pi^-$ . We ran with a number of thick targets: C (4" and 8"), Al(5" and 6.5"), Cu (4") and Pb (2" and 3"). Events were selected using the pretrigger only, however the trigger processor results were also recorded. The off-line track and mass

reconstruction was based entirely on muon chamber and D-station. The momentum and mass resolution are therefore determined by the multiple scattering of the muons. We have checked that the mass resolution function can be roughly approximated by a gaussian with a width of 550 MeV. It improves considerably once the upstream tracking information is available, when it is expected to be better than 150 MeV.

The measured, uncorrected  $x_f$  distribution for  $\mu^+\mu^-$  with mass  $> 2.5$  GeV and the acceptance of our apparatus are shown in Fig. 2. For the further analysis we have restricted our data to the  $x_f$  region  $0.2 < x_f < 0.8$  where our integrated acceptance is approximately 40%.

The  $\mu^+\mu^-$  mass distribution for all targets combined is shown in Fig. 3. The fit of an exponential background and a Monte Carlo predicted mass resolution function yielded a total sample of 900  $\psi$ 's. The results of the fit are shown in Fig. 3.

The  $p_T$  acceptance of the apparatus is essentially flat up to momentum of 5 GeV/c. The average observed  $p_T$  is 1.4 GeV/c, which is consistent with results of previous experiments and effects of the smearing due to the measurement resolution.

Mass fits were repeated for different data samples to establish contributions from individual targets and to check effects of target thickness, backscatter of target debris toward the muon veto wall, halo muons contamination etc. The resulting cross sections are presented in Fig. 4. They were corrected for the acceptance estimated to be  $0.41 \pm 0.03$  for  $0.2 < x_f < 0.8$ . Other corrections: for the pretrigger and chambers efficiencies, software losses, Drell-Yan pairs, target thickness, non-vertex interactions,  $x_f$  smearing, etc. have not yet been applied. We estimate that their net effect could increase the  $\psi$  production rate by at most 15% and should be almost target independent. The observed rates are consistent with the extrapolated  $\pi\pi$  data<sup>12</sup>. A fit to an expression  $\sigma \sim A^\alpha$  yields  $\alpha = 0.87 \pm 0.06$ .

#### 4. Conclusions

Preliminary results of our experiment indicate that the forward production of  $\psi$  exhibit  $A^{0.9}$  rather than  $A^{1.0}$  dependence in  $\pi^- - A$  collisions at 530 GeV/c.

The data presented here were collected in the Fall of 1987. During January of 1988 the entire E672/E706 apparatus was operating. Almost 2 million dimuon triggers were recorded with pion and proton beams at 530 GeV/c incident on Be and Cu targets. The projected total data sample is: 5000  $\psi$  events; 600  $\chi \rightarrow \psi + \gamma$  events with  $E_\gamma > 8$  GeV; 8 beauty events with either one  $B \rightarrow \psi + X$  decay or two B semileptonic decays with  $\mu\mu$  mass  $> 2.5$  GeV.

During the 1989/1990 Fermilab fixed target run we expect to collect an order of magnitude more data.

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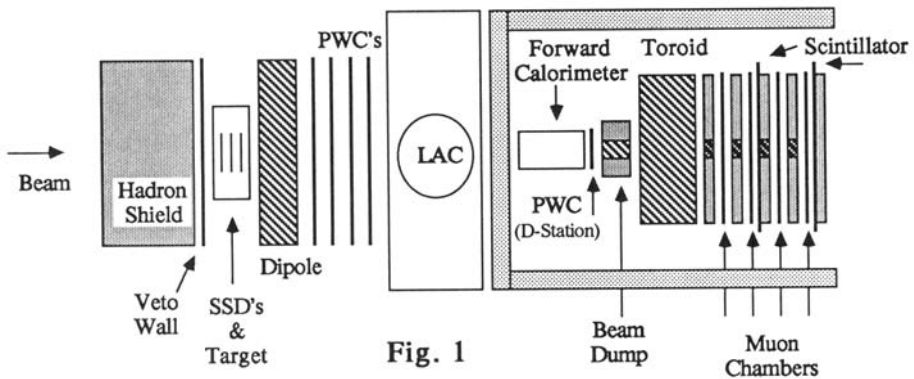


Fig. 1

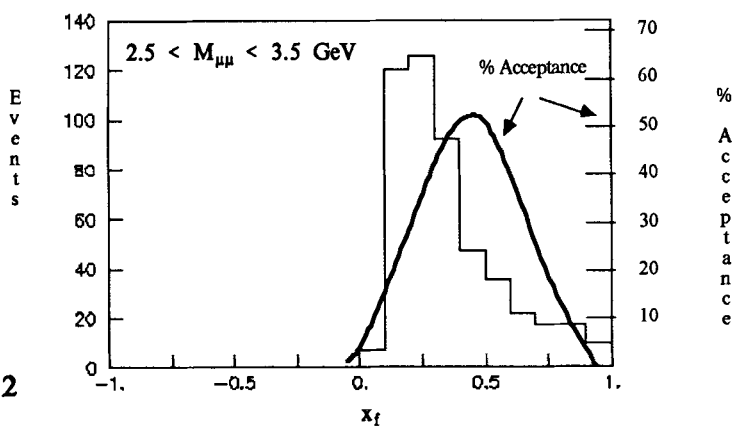


Fig. 2

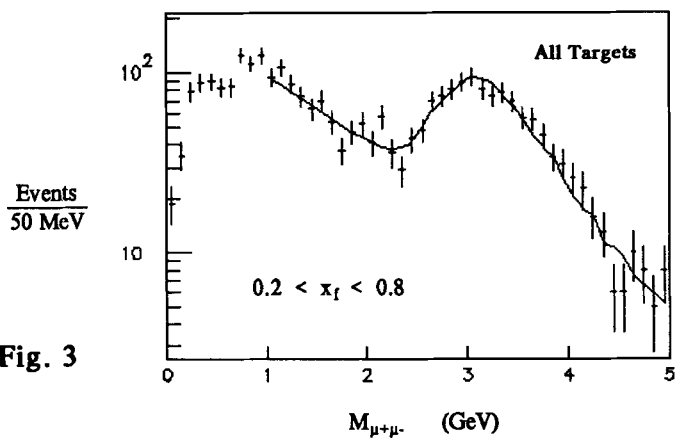


Fig. 3

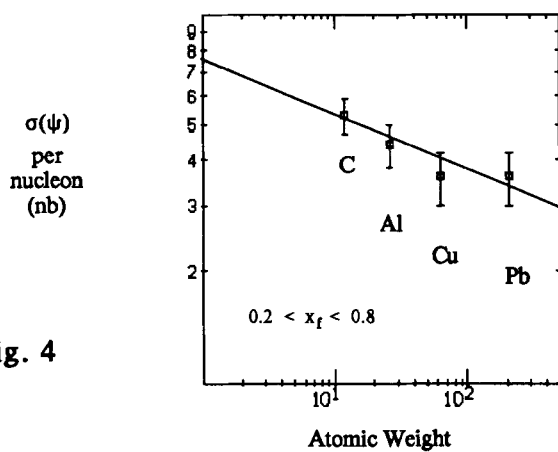


Fig. 4