Hadron Production in COMPASS

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Abstract. COMPASS is a fixed target experiment running with a 160 GeV muon beam at CERN's SPS accelerator. It is aimed at the study of the nucleon spin structure using a polarized muon beam and a polarized ^{6}LiD target. In a second phase it will investigate charmed hadrons and hadrons with gluonic degrees of freedom and study Primakoff and diffractive scattering. We present the status of analysis of the production of hadrons by muons.

PHYSICS OF COMPASS

The COMPASS collaboration was founded in 1996 to perform a number of measurements in hadron physics ranging from polarized structure functions examined with deep inelastic muon scattering to topics like light meson spectroscopy and the study of exotic hadrons [1]. After the first phase of the COMPASS experiment focusing on the contribution of gluons to the polarized structure function of the nucleon, a second phase is planned to address more topics with hadron beams.

Physics with the Muon Beam

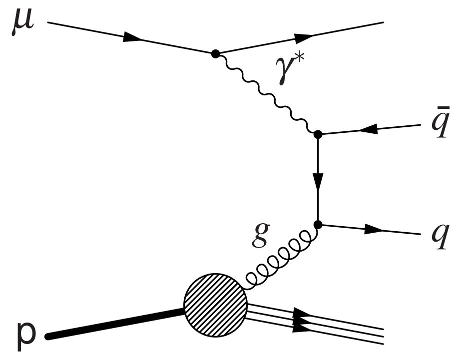

FIGURE 1. Photon gluon fusion process.

In experiments at SLAC, DESY and CERN the spin structure of nucleons has been explored[2]. It was observed, that the spin carried by quarks inside the nucleon only contributes about one third to the total nucleon spin. This surprising result leads to the conclusion that the remaining part should come from gluons or from angular momentum. The first main objective of COMPASS is to measure this contribution from gluons.

In deep inelastic scattering gluons in the target nucleon can couple to the scattering lepton via the photon gluon fusion process. For charm quarks this process is the dominant mode of production and therefore measuring asymmetries of open charm production in deep inelastic scattering is a clean way to measure the gluon spin in the nucleon.

In case of lighter quarks being produced, the photon gluon fusion process can be selected by requiring two hadrons or jets with high transverse momentum.

The measurement is being performed in COMPASS by scattering a polarised muon beam of 160 GeV on a polarised target. As target material ^{6}LiD is used to measure the nucleon spin structure, because of its low dilution factor at nevertheless high values of polarisation . The material is polarised by dynamic nuclear polarisation in a magnetic field with microwaves at a temperature of a few mK.

As dominant signature COMPASS is looking for D^0 mesons in the decay $D^0 \to K^-\pi^+$. To reduce background the neutral D's are tagged by requiring them to come from the decay $D^{*+} \to D^0\pi^+$. COMPASS will be able to measure the gluon polarisation to about 10-14% in open charm production. In addition a statistical error of about 5% can be reached from high p_T hadron pairs, however with a higher systematic error from the model dependence of the background description.

In addition COMPASS studies the flavour decomposition of the quark helicity distributions and the transverse spin distribution.

Physics with Hadron Beams

Primakoff Scattering. Primakoff scattering can be seen as Compton scattering in inverse kinematics: a particle is scattered in the Coulomb field of a heavy nucleus. For unstable particles for which the direct process would not be possible this process gives access to their electric and magnetic polarisabilities. For these quantities predictions are made by chiral perturbation theory. More details on the physics of Primakoff scattering are discussed elsewhere [5].

COMPASS will be able to measure the polarisability of the pion with an error of about 5% and for the first time could measure it for kaons as well.

Study of Gluonic Systems. Central collisions of a proton beam on a proton target provide a gluon-rich environment in the double pomeron exchange mechanism. This is assumed to efficiently produce glueballs and exotic non-$q\overline{q}$ mesons predicted by QCD. A candidate for the scalar glueball ground state 0^{++} is the f_0 at 1500 MeV/c observed by the experiments Crystal Barrel and WA102[3].

COMPASS will detect many decay modes of this state and in addition access the mass region above 2 GeV where the first excited state, the tensor glueball 2^{++} is predicted around 2.3 GeV by lattice QCD.

COMPASS will have a very good acceptance owing to its two-stage spectrometer and the large acceptance target detector. In addition a kinematical filter for glueballs is possible by requiring low p_T hadron jets [4]. COMPASS will also be able to contribute significantly to the search for exotic mesons.

Doubly Charmed Baryons. A further goal of the hadron program, to look for doubly charmed baryons (DCB), has been studied in recent reviews [6, 7]. Because of their particular structure decisive predictions are made by HQET[8, 9]. Their dynamics should be similar to heavy mesons, where one light mesons is coupled to one heavy partner. The decays of DCB offer a unique way to study spectator effects, since the contribution of each light quark flavour can be observed separately. The lifetimes of DCB are expected in the range of 100–200 fs [10] or even up to 1 ps for Ξ_{cc}^{++} [11].

Recently Fermilab experiment Selex (E781) has made observations of DCB in decay channels to Λ_c plus mesons [12]. The production process seems to favour baryon beams and is very strong in the forward direction, where the largest part of SELEX's acceptance is. Based on these measurements COMPASS could observe up to 17,000 DCB in one year of beamtime. This would open up the possibility of detailed spectroscopy and precise tests of theoretical predictions. Conservative estimates assuming the double charm production probability to drop with the square of the single charm fraction would still yield up to 200 reconstructed decays.

OVERVIEW OF THE EXPERIMENT

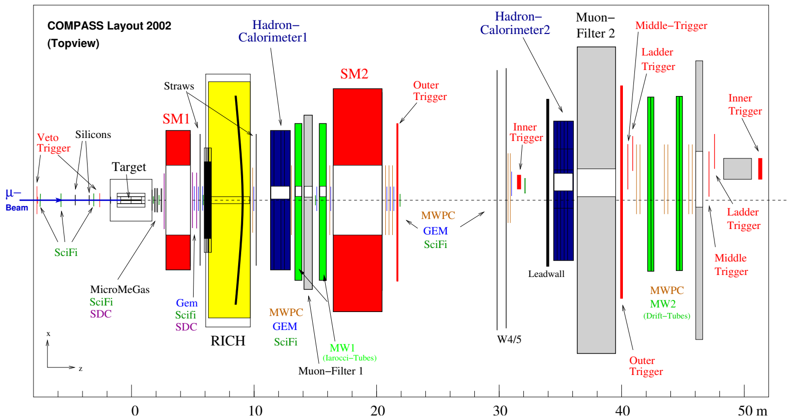

FIGURE 2. General setup of the COMPASS spectrometer.

Spectrometer. COMPASS uses a double magnetic spectrometer with tracking, electromagnetic and hadronic calorimetry and particle identification in each section: the first stage detects low momentum particles at large angles (± 180 mrad). High momentum particles are analyzed in the second part (± 25 mrad) using a large lever arm and a higher magnetic field than in the first. In this way an angular resolution down to 10 μrad (for small scattering angles) and a transverse resolution down to 7 μm can be achieved. A schematic view of the spectrometer is given in fig. 2. For the hadron beam programmes the gap of the first spectrometer magnet can be reduced to provide a higher field for the higher beam energy and also a smaller stray field in the tracking zones.

The tracking system is built up from a set of **L**arge **A**ngle **T**rackers (**LAT**) covering the outer region with lowest track density and **S**mall **A**ngle **T**rackers (**SAT**) for the inner regions. So-called *tracking stations* are distributed all over the spectrometer and consist of three different detector types staggered, each smaller one having finer granularity and rate capability and covering with some overlap a central hole in the next larger one. For the innermost part, directly in the beam, silicon detectors [13] and scintillating fibers are used. The LAT are small cell size drift chambers, straw chambers[14] and further downstream MWPC and large cell size drift chambers. The very important inner trackers between the beam region and the LAT consist of Micromegas [15] before the first magnet and GEM detectors [16] after that.

For identification of charged particles a RICH detector with a 3 m long C_4F_{10} radiator between the two spectrometer magnets is used. Further downstream hadronic calorimeters provide the energy measurement needed to help forming a first level trigger. For the reconstruction of γ and π^0 an electromagnetic leadglass calorimeter placed in front of the second HCAL is available since 2003. Behind the calorimeters two muon filters allow to identify muons. Hodoscopes at the second muon filter serve as main trigger detectors and are correlated by means of fast lookup tables to provide kinematic selection and target pointing.

Data Taking in 2002. In 2002 COMPASS had its first major physics data taking period. After a long setup period, where many new detectors were commissioned and calibrated, 57 days were spent measuring with the target being longitudinally polarised (1.2 fb^{-1}), 19 days with transverse polarisation (0.3 fb^{-1}. In total about 5×10^9 events and 260 TB of data were recorded.

FIRST DATA ANALYSIS

Only a brief account of the status of the data analysis can be given here. The analysis is still in progress and being the first year with physics results the optimisation of precise calibrations and refined reconstruction algorithms is still going on. In particular detailed systematic studies still have to be performed for the major part of results. Therefore all presented results have to be considered as preliminary and subject to change.

Exclusive Production of ρ and ϕ

The exclusive production of vector mesons in COMPASS was studied on the base of about 1/6 of the data by reconstructing the decays $\rho \to \pi^+\pi^-$ and $\phi \to K^+K^-$ [17]. To ensure exclusive production a cut on the missing energy of $-2 < \Delta E < 2.5$ GeV was applied. The kinematic range was $10^{-3} < Q^2 < 10$ $(\text{GeV/c})^2$ and $7.5 < W < 16$ GeV. In this sample 1.3 million ρ^0 and 42,000 ϕ were reconstructed.

The dependency on t and the angular distributions of ρ were studied. An approximate validity of s-channel helicity conservation was noted. The final statistics will allow improved measurements of both unpolarised and polarised observables for these channels.

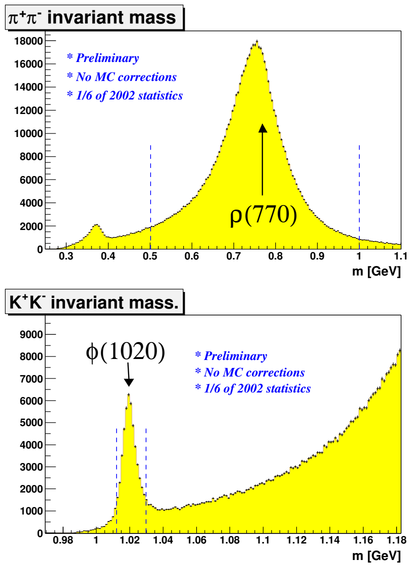

FIGURE 3. Mass distributions of ρ and ϕ.

Production of J/Ψ

In about 20% of the 2002 data production of $J/\Psi \to \mu^+\mu^-$ was studied. Being mostly elastically produced the signal is not useful for the measurement of $\Delta G/G$. A signal of 213 ± 17 J/Ψ at a mass of $m = 3103 \pm 6$ MeV was observed.

It has to be noted that the observation of J/Ψ was suppressed in 2002 by the DIS trigger. For the data taking in 2003 a dedicated J/Ψ trigger was set up.

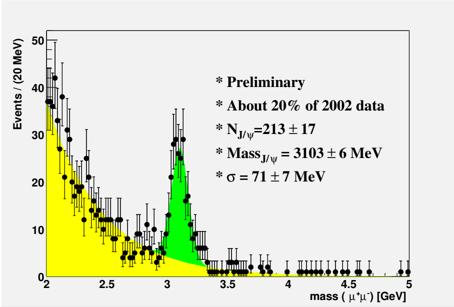

FIGURE 4. Mass distribution of $J/\Psi \to \mu^+\mu^-$.

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