COSY Beam Request

ANKE: Commissioning, Calibration and Study of NN Final State Interaction in Single Pion Production

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Abstract

A beam time of two weeks is requested for the commissioning and calibration of the ANKE spectrometer and for NN FSI studies. As part of this process it is proposed to perform angle and momentum measurements of pions emitted from the $pp \to \pi^+ d$ reaction in the forward direction. Combining these measurements with those of $pp \to \pi pn$ studied both inclusively and with two particles in coincidence should give new information on the spin structure in pion production leading to low mass pn pairs.

Motivation.

The $pp \to \pi^+ d$ reaction is the standard calibration reaction at medium energies. The cross sections are high, and their values are known precisely enough to be used for a reliable normalization of the data. Moreover at a fixed proton beam energy the pions from this reaction have well defined momenta with small spread ($< 0.5\%$) for a rather wide angular interval (up to 5^o in the forward direction) to be used for measurements of the device's momentum acceptance and resolution.

The natural generalization of this two body reaction is the $pp \to \pi^+ pn$ reaction in that part of the phase space where the two final nucleons emerge with low relative energies and where a strong final state interaction takes place (FSI region). The precise knowledge of the NN final state interaction is of a special importance for the near–threshold meson production physics where the FSI region accounts for most of the phase space.

Inclusive pion energy (momentum) spectra in the FSI region were measured in several experiments /1/ in the beam energy range from 400 MeV to 1000 MeV. In contrast, $\pi^+ p$ correlations were studied in the FSI region only in one experiment at 800 MeV /2/. The analysis of these data within two different approaches gives no unambiguous answer to the spin content of the low mass pn pairs. The one-pion-exchange model taken in conjunction with the conventional Watson formulation /3/ gives a satisfactory description of all the existing $pp \to \pi^+ pn$ experimental data when the spin singlet fraction is taken as about one third of the total, essentially independent of the energy in the range 400–1000 MeV /4/. The other FSI model /5/, predicting the inclusive measurements of the final np S-wave spin-triplet spectrum from the cross section for $pp \rightarrow \pi^+ d$, results in a singlet fraction of less than 0.1 at 400 MeV, increasing up to one third at 1000 MeV.

It is proposed to perform systematic high statistics precision measurements of inclusive (Fig.1 (see Fig.7 in proposal)) and correlated (Fig.2 (see Fig.8 in proposal)) pion and proton spectra at 14 beam energies in the range 300 – 800 MeV. Normalization will be made using the simultaneously measured reaction $pp \rightarrow \pi^+ d$.

Calibration and FSI studies.

The experiment will be done at ANKE spectrometer in the mode with the 10.6^o beam deflection angle, C and CH_2 targets and the Side Detection system (23 start counters, 15 stop telescopes, the Side Hodoscope of 6 scintillation counters and 2 three-plane MWPCs) will be used in the experiment (Fig.3 (see Fig.5 a and b in proposal)). The fast pion trigger will be similar to the kaon trigger which will be used later in the kaon production experiments. Pions will be selected by fast coincidences of signals from a stop counter and from any of the corresponding start counters and by fast energy loss cuts. No changes in the device are foreseen through all the measurements, only the projectile energy has to be adapted: namely, to start measurements at a certain energy one must only correct it by positioning the peak of nearly monoenergetic pions from $pp \rightarrow \pi^+ d$ ($\theta_\pi < 5^o$) to the centre of the corresponding stop counter (e.g. as in Fig.4 (see Fig.6 in proposal)).

The measurements for each telescope (or setting of T_p) will be done with three targets (CH_2 - 3 hours, C - 3 hours, empty - 1 hour) and the information from ADCs and TDCs of all the scintillation counters together with the MWPCs' data will be recorded. The full pion momentum spectrum as well as correlated pion and proton spectra will be obtained after the particle identification is done from the analysis of TOF and energy loss spectra, making also use of the information from Cherenkov and VETO counters and track - reconstruction on the basis of the MWPCs' data and the D2 magnetic field map.

Momentum spectra of pions from $pp \rightarrow \pi^+ ...$ reaction will be obtained after the carbon data have been normalized to the polyethelene data in the pion momentum region which is kinematically forbidden for $pp \rightarrow \pi^+ ...$ (Fig.4, telescope 13) and subtracted from CH_2 data.

If the highest recording speed is equal to 5000 s^{-1} (achieved at a beam intensity 10^8 p/burst and a luminosity 10^{31} cm^{-2}s^{-1}) then during the 3 hours' measurement at each energy with CH_2 or C targets, $5 \cdot 10^7$ events will be collected for the whole pion spectrum with $5 \cdot 10^5$ events in the pion momentum FSI region (20–40 points in the $\delta p/p = 10\%$ part of the momentum spectrum close to the pion peak of the $pp \rightarrow \pi^+ d$ for $\theta_\pi < 5^o$, channels 235–260 in Fig.4) and about 10^4 events in the $\pi^+ p$ correlation peaks (10–20 points in the 60 MeV momentum region of the proton correlation spectrum for $\theta_\pi < 2.5^o$ and $\theta_p < 2.5^o$, peak in Fig.2).

Since inclusive pion spectra in the FSI region are strongly dependent on the ANKE momentum resolution whereas correlation spectra are most sensitive to the geometric factors (e.g. angular acceptance) simultaneous measurements of both these spectra with high statistics will not only give good cross-checks of NN FSI physics but will obviously help for a better understanding of the device. It is also important to study with high accuracy the TOF spectra which will have more than 10^6 events. This is not simply to confirm the TOF resolution (it is known from laboratory tests with cosmics and radioactive sources) but rather to study the tails of TOF distributions at the level $10^{-4} - 10^{-5}$ of the maximum of these distributions. This knowledge is absolutely necessary for the future experiments on kaon production from nuclei, when the pion background exceeds the kaon count rate by more than 10^4 times.

Measurements at 14 beam energies will need (1h + 3h + 3h +1h)$\cdot$14 = 112 hours. It is reasonable (from experience) to assume 30% beam time losses, and that gives about 150 hours.

Commissioning.

The ANKE spectrometer is a device just built, whose components (including CH_2 target, produced and tested at Koln University) have been tested under laboratory conditions but have never been used in a COSY experiment. The ANKE magnetic system will be for the first time implanted into the COSY ring. Obviously ANKE needs a machine development time which may be longer than the one week traditionally spent at COSY for experiments with the conventional COSY set up. The experiment COSY–38 can be done only at the ANKE mode with the largest beam deflection angle (10.6°) and with a longer then standard beam orbit. Experience has to be gained with these new conditions. Moreover the experiment will be done over a wide beam momentum range with approximately 5–10% change of the beam momentum every 8 hours, with fine tuning in 2–3 steps of 0.5–1% beam momentum change within 1 hour. These, again, are procedures which have to be studied when ANKE is in the ring.

ANKE also needs additional beam time for the commissioning of side detection system. This will be done at the fixed beam energy (800 MeV) with pions and protons from the carbon target. First we must guarantee nearly 100% pion detection efficiency of our detection system. It will be checked step-by-step for every counter. Triggering from the mean-timer of a stop counter, the pulse-height distributions from top and bottom PMs are checked for the pions which hit top, bottom and central parts of the plastic scintillator (10 cm regions defined from top-bottom TOF). For the central parts the amplitudes in maxima of the top and bottom pion pulse height distributions must be the same within 10% and for the top and bottom parts (close to PM) pion pulse height distributions must be above the threshold. If necessary, the PM high voltages must be changed. The same check is done for all the counters of this stop telescope and after that fast coincidences of this stop counter with any of several start counters (six on the average) are done and all these start counters are checked identically to the procedure for the stop counters together with start-stop TOF spectra. MWPCs are tested in parallel.

This procedure is repeated for all the stop counters, included into the fast trigger (15 telescopes and 4 counters of the Side Hodoscope), during about 7 hours per each stop-start combination or in total 7·19=133 hours without taking into account unavoidable and difficult-to-estimate time losses.

After these 133 hours we will know the pion detection efficiency in all our counters, understand our fast trigger, can look at any ADC and TDC spectra, record and ray-trace the events to reconstruct the target spot and to see particles spatial distribution at the focal plane and to make necessary angular cuts.

Then we can start the final checks at the two most critical beam energies with CH_2 and C targets. At 300 MeV the most part of the $pp \to \pi^+$... phase space is in the FSI region and the best pion energy resolution is expected but CH_2 and beam survival times must be checked (will be the lowest) in cooperation with the necessity to increase the beam intensity and to change fast trigger (low cross sections, high $pC \to \pi^+$... and may be direct background of particles not passing through D2). At 600 MeV the cross section for $pp \to \pi^+$... in the FSI region is largest but correlated protons and pions hit the same stop telescope, passing the D2 magnet near its corner at rather small angles ($< 45^o$) to the MWPCs, and there is the necessity to change the fast trigger (by say including the Cherenkov's counter signal into the fast trigger) and the possibility of having fast proton identification (by increasing the threshold in the δE counter discriminator) must be studied.

After answering all these questions the programme on two-body-reaction calibrations and on NN FSI studies (discussed above) will start.

Beam time request.

In summary the ANKE collaboration has the following COSY beam request:

- two weeks beam time after the machine development for ANKE (preferably at the end of January – beginning of February)

- beam energy 800 MeV, carbon internal target (6 days for commissioning of ANKE Side Detector system, can partly be done with the further machine development, if necessary)

- Beam energies 300 and 600 MeV, CH_2 and C internal targets (1 day for final checks at critical energies)

- 14 beam energies in the range 300–800 MeV, CH_2 and C internal targets (7 days for the calibration and NN FSI data taking)

References

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