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Search for ppK- state in p+p@3.1 GeV

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Recently several experimental approaches have been developed to study the existence of the ppK^- bound state. One possibility, which we have pursued with the FOPI spectrometer at GSI, is to exploit proton induced reactions.

We report on the development, construction and the performance of a dedicated Λ-trigger, which have been employed in several tests at GSI with a proton beam of 3.0 GeV and 3.1 GeV incident energy. This Λ-trigger should enhance the detection probability of the possibly formed ppK^- state in its decay into Λ + p.

In this proceedings we will present the results of the experimental development, the performance of the Λ-Trigger and results from the ongoing analysis of the recently collected data.

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1. Introduction

In the last years an extensively discussion has been carried out about the possible existence of kaonic nuclear states. Based on the assumption that the the $\Lambda(1405)$ is molecular state with a strong $K^- p$ component, the prediction was made, the by adding further nucleons to this system, kaonic bound states could be produced. The lightest candidate then would be the ppK^- bound state, with a predicted mass of M=2322 MeV/c^2, a binding energy of $B_{ppK^-} = 48 MeV$ and a width of $\Gamma = 61$ MeV [1, 2], assuming an empirical $p - K^-$ Potential.

Different theoretical calculation, based on a SU(3)-Langrangian Ansatz, predicts a smaller binding energy ($B_{ppK^-} = 20$ MeV) and a similar width ($\Gamma \sim 40 - 70$ MeV) [4]. Recent results from the DISTO collaboration have given the indication for the existence of that ppK^- [5]. Further the hypothesis has been put forward, that this state is suggested to be populated quite favorably in a $p + p \rightarrow ppK^- + K^+$ reaction due to the large momentum transfer and the small impact parameter of the reaction (s. figure 1).

In order to reduce the background we have planed to do a fully exclusive measurement of the reaction $p + p \rightarrow ppK^- + K^+ \rightarrow [\Lambda + p] + K^+ \rightarrow [[\pi^- + p] + p] + K^+$, to search for the ppK^- in the K^+-missing-mass spectrum and the Λp-invariant-mass spectrum.

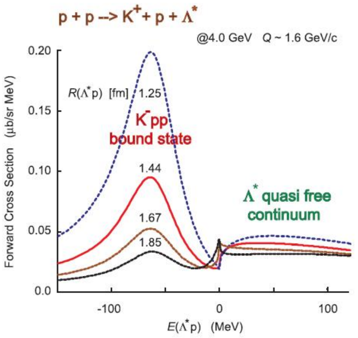

Figure 1: Theoretical calculation of the production crosssection of ppK^- in p+p reactions with an incident energy of 4.0 GeV for different rms-radii of the ppK^-. The production of a bound state is favored against the quasi free production of Λ^* p ([1, 2]).

2. The p+p Experiment with FOPI at GSI

For the exclusive measurements of the ppK^- a detector with a high geometrical acceptance at a facility, which is able to produce a proton beam up to 3.5 GeV is necessary. These conditions are forfilled at the FOPI Spectrometer at the SIS18 at the GSI. This spectrometer cover an angular acceptance from about 5° to 113° in the polar angle and nearly 360° in the azimuthal angle.

Figure 2 shows the FOPI spectrometer. It consists of two drift chambers, the Helitron for lower and the CDC for higher polar angles (yellow). The CDC is surrounded by a scintillator(blue) and a RPC(white) time of flight barrel. All these detector are located inside a 0.6 Tesla solenoid magnetic field. The PLAWA, which measures the time of flight at small polar angles, completes the FOPI spectrometer.

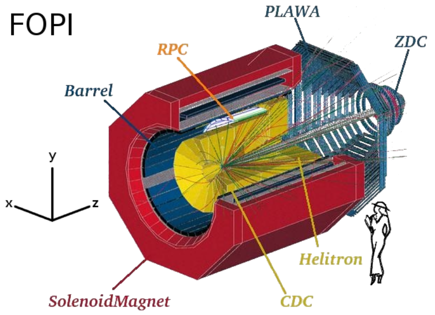

Figure 2: The FOPI spectrometer. The driftchambers CDC and Helitron and the time of flight detector scintillator and RPC barrel are surrounded by a solenoid magnet. Behind the magnet is the PLAWA time of flight detector located.

Recent heavy ion experiments at FOPI had shown, that with the RPC detectors it is possible to determine the time of flight with a resolution of 115 ps, which allows kaon identification up to an momentum of 1 GeV/c. Figure 3 show the momentum times charge versus velocity - recorded with Ni+Ni (1,93 AGeV) - for RPC (right) in comparison to the old Barrel detectors (left), where K^+ could be separated from protons and pions up to a momentum of about 0.5 GeV/cf.

Due to the fact, that the FOPI spectrometer was build for heavy ion experiments, some additional detectors had to be build to run a proton on proton reaction. The beamline had to be upgraded with a new start and a veto detector to fit to the beam constraints.

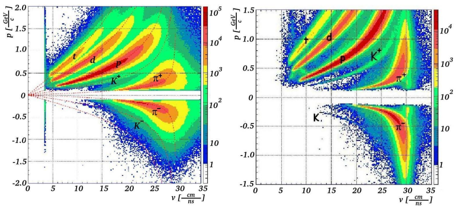

Figure 3: Momentum times charge vs. velocity - recorded with Ni+Ni (1.93 AGeV) - of Barrel (left) and RPC(right). With the scintillator barrel Kaon separation is possible up to a momentum of 0.5 GeV/c, with the RPC up to 1 GeV/c

Furthermore a detector (SiΛViO : Silicon for Λ-Vertexing and Identification Online) near the target was necessary for two reasons: On the one side as a trigger detector for events, containing a Λ particle. Figure 4 shows the schematic drawing of SiΛViO with typical pK^+ Λ event. The trigger detector consist of two layers of segmented silicon detector, which distance to the target was choosen in that way, that around 60% of the produced Λ particles are decaying in between the the first and the second layer. Since the Λ hyperon is chargeless, it does not make a signal in the first layer. The decay particles from its charged decay - proton and pion - are creating a signal in the second layer. The resulting hit multiplicity difference is used to create a trigger signal.

On the other side SiΛViO should improve the tracking for particles which are emitted to small polar angles. Since the second layer of SiΛViO consists of double sided silicon strip detectors a hit point is determined. By refitting the tracks, measured by the forward detector Helitron and Plawa, with this hit point the resolution of the momentum and the secondary vertex resolution should be improved.

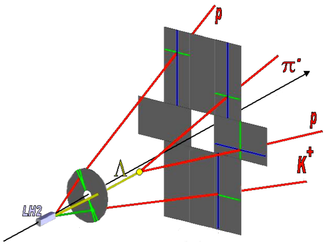

Figure 4: Schematic view of SiΛViO with a typical $pK^+\Lambda$. The neutral Λ hyperon does not created a signal in the first layer. The decay particles p and π create signal in the second layer, which leads to a higher hit multiplicity in the second layer.

3. Acceptance Simulations

Before we run the main experiment, we had to simulate the event and background acceptance of the different trigger levels.

As trigger condition for the first level trigger (LVL1) at least one particle hit in the PLAWA (forward) and at least one particle in the scintillator or the RPC Barrel (backward) was required.

The second level trigger condition (LVL2) was, in addition to the LVL1 trigger condition, the trigger signal created by SiΛViO, which required at least one hit in the first layer and at least two hits in the second layer.

For these two trigger conditions we simulated the total event acceptance for the signal channel (p+p $\rightarrow$ p + K^+ + Λ) and for the background (p + p $\rightarrow$ X), which was simulated by UrQMD. Table 1 shows the different acceptance values and the LVL1 to LVL2 reduction. From these numbers we could deduce a higher background suppression created by SiΛViO and an enrichment of p$K^+\Lambda$ events of about a factor 4.8.

	LVL1	LVL2	LVL1→LVL2
Signal (p+p $\rightarrow$ p + K^+ + Λ)	39%	6.78%	1/5.8
Background (p + p $\rightarrow$ X)	28.4%	1.4%	1/20.3

Table 1: Total event acceptance of signal (p+p $\rightarrow$ p + K^+ + Λ) and background (p + p $\rightarrow$ X)

4. First Results from the Beam time

In August 2009 we had 14 days of production experiment. At this experiment we had a proton beam with an intensity of 1 MHz and a liquid hydrogen target with a length of 2 cm.

During this beam time we recorded around 80 million LVL2 trigger events and around 50 million events with ”SiΛVio only” triggers.

From the trigger rates we could deduce a LVL1 to LVL2 reduction of about 1/11 during the experiment. At the end we were also running without target, where we received a LVL1 to LVL2 reduction of 1/42.

Furthermore we determined that at most 16% of the trigger events are not coming from target. That lead to the statement, that SiΛViO mainly triggers on events, which are coming from the target.

One important question is, whether we are able to identify kaons in our data with the RPC barrel detector. With a first rough calibration we received the spectrum plotted in figure 5, which shows, that K^+ could be separated up to 0.6 GeV/c from protons and pions [6].

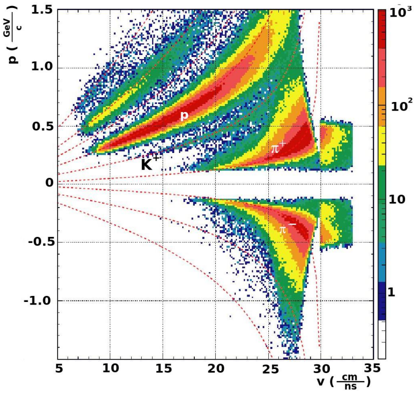

Figure 5: Momentum times charge vs. velocity from p-p-experiment with rough time calibration

5. Summary and Outlook

The proton-proton beam time with FOPI at GSI has taken place in August 2009. From first results we have seen, that the trigger detector SiΛViO has worked quite proper in triggering mainly on target events and in this was reduces the triggerrate of about 1/11. Further we were able to identify first kaons with the RPC detector up to a momentum of 0.6 GeV/c.

At the moment we are spending quite intensiv work in the reconstruction of Λ particles in forward direction, by improving the momentum and vertex resolution using the SiΛViO hit point and improving the time of flight resolution by fine calibration of the RPC detector and calibrating the start detector.

References

[1] T. Yamazaki and Y. Akaishi, Phys. Lett. B 535 (2002) 044005

[2] T. Yamazaki and Y. Akaishi, Phys. Rev. C 65 (2002) 70

[3] T. Yamazaki and Y. Akaishi, Phys. Rev. C 76 (2007) 045201

[4] A. Dote, T. Hyodo and W. Weise, Phys. Rev. C 79 (2009) 014003

[5] M. Maggiora, proceddings Hyp-X 09

[6] Norbert Hermann, private communication