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for the E31 collaboration

To the PAC chairperson and members:

I am writing to request for beam time allocation for the E31 experiment, "Spectroscopic study of hyperon resonances below $\bar{K}N$ threshold via the (K^-,n) reaction on Deuteron". The 16th PAC kindly recommended the second stage approval for E31. Before the last summer shutdown, a pilot run for E31 was scheduled for a few days although it was not realized because of the J-PARC accident. However, the readiness for the E31 experiment has been confirmed through physics runs for E15. Based on the analysis of E15 data, we refine the beam time request of two weeks (16 days) for the pilot run assuming a 24-kW beam on T1. It is desired in order to clarify a sensitivity to the $I = 0$ and $I = 1$ amplitudes in the d(K^-,n) reaction below the $\bar{K}N$ threshold by measuring the $\pi^{\pm}\Sigma^{\mp}$ final states in reasonable statistics.

The E31 experiment aims at investigating the Λ(1405) as a dynamically generated meson-baryon resonant state. According to a recent literature [1], two resonance poles appear between the $\bar{K}N$ and $\pi\Sigma$ thresholds for the case of an energy-dependent meson-baryon potential, as predicted by a chiral unitary model [2]. On the other hand, one resonance pole appears for the case of an energy-independent potential. Since both potentials reproduce low-energy $\bar{K}N$ scattering data, studies of different reactions are of importance. We remind that the d(K^-,n) reaction enhances the S-wave $\bar{K}N$ scattering amplitude at the neutron forward angle [3]. Thus, the Λ(1405) production via d(K^-,n) reaction will give us unique information to identify the interaction between anti-kaon and nucleon, i.e. the interactions acting as energy dependent way or not. In particular, a recent theoretical calculation suggests that the d(K^-,n) missing mass spectrum strongly depends on the above-mentioned (energy-dependent or not) potentials [4].

As for recent experimental situations, the CLAS collaboration reported a detailed analysis of the Λ(1405) line shapes for 3 final $\pi\Sigma$ states in the p(γ, K^+)πΣ reactions (Fig. 1). The result shows interference between the $I = 0$ and $I = 1$ amplitudes [5], although the differences seem different from those predicted by a theoretical calculation [6]. The Λ(1405) spectra in missing masses of the pp→$pK^+\pi^{\mp}\Sigma^{\pm}$ reactions are reported by the

HADES collaboration, as shown in Fig. 2-left [7]. They claim that the peak position corresponding to the Λ(1405) is shifted clearly below 1400 MeV/c^2. A theoretical analysis is made to fit the HADES data with giving its best-fit for Λ(1405) of $M = 1405^{+11}_{-9}$ MeV/c^2, and $\Gamma = 62\pm10$ MeV [8]. However, an attempt to explain the observed spectrum with a Λ(1405) line shape based on two-pole amplitudes has been also reported, as shown in Fig. 2-right [9]. Thus, measurements on different reactions are strongly desired. Therefore, we prefer to carry out a pilot run to confirm if the d(K$^-$,n) reaction really enhance the S-wave $\bar{K}N$ scattering amplitude to form Λ(1405). From this pilot run, we will be able to evaluate a sensitivity to the $I = 0$ and $I = 1$ amplitudes in the d(K$^-$,n) reaction below the $\bar{K}N$ threshold by measuring the $\pi^{\pm}\Sigma^{\mp}$ final states in reasonable statistics. It should be note that the detail study of the $\bar{K}N$ interaction and Λ(1405) would require the full statistics of the experiment which has been requested in the proposal of the E31 experiment, where we will measure the $\pi^0\Sigma^0$ decay mode in order to extract the $I = 0$ amplitude purely.

Readiness for the E31 experiment has been confirmed through physics runs for E15 because of the setup for E31 is identical (Fig. 3 and 4) except for the target system. An operation of the E31 deuterium target system was successfully done at the K1.8BR area in last April, as shown in Fig. 5.

We refine the beam time request for the pilot run as described below.

First, we need 1 day for starting up the experimental apparatus. Second, we need a calibration run with the Hydrogen target for 4 days, where we will measure the neutron detection efficiency of the neutron counter (NC) by using the p(K$^-$,K^0_s)n reaction. We expect 10^4 events to determine the efficiency at an error level of 1 %. We need another 1 day to switch the target from Hydrogen to Deuterium. During this occasion, we will take a target-empty run for 1 shift. Finally, we request the first physics run for 10 days. Expected yields are estimated, as listed in Table I, which are obtained based on detailed analysis of E15 data taken just before the J-PARC accident. The details of the E15 data analysis are reported separately [10]. Here, we simply assume the beam intensity of the previous run. We found rather small efficiency in beam line part due to a selection of single tracks for the kaon beam and a fiducial cut for the beam size at the target. The reason to apply the fiducial cut is that the beam size is larger than that of the target cell size, which is hardly controlled by tuning the beam line magnets. In this pilot run, we expect to collect 750 and 120 events for $\pi^+\Sigma^-$ and $\pi^-\Sigma^+$ decay modes. For the $\pi^+\Sigma^-$ mode, the statistics will be higher than that obtained in the previous bubble chamber experiment [11]. The $\pi^-\Sigma^+$ mode is hither-to-unreported in the d(K$^-$,n) reaction. Thus, our data are expected to provide information on the $I = 0$ and $I = 1$ amplitudes in the d(K^-,n) reaction for the first time.

In summary, we request:

1. Engineering run for 1 day,
2. Calibration run for 4 days (Hydrogen target),
3. Target change from Hydrogen to Deuterium for 1 day (including 1 shift for a target-empty run), and
4. Physics run for 10 days (Deuterium target).

Among these, the engineering and calibration runs can be shared with E15 if the beam time allocation for E31 is coordinated timely, taking into account the fact that it takes at least a week to switch from the hydrogen (deuterium) target to the ^{3}He target.

References:

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Table I: Yield estimation

Beam Intensity	1.4x10^5 ppp	24 kW primary beam
D_2 Target (Fiducial Vol.)	10 cm	Density: 0.169 g/cm^2
Efficiency		
Beam tracking	0.63	Select single tracks
Fiducial cut for the beam size	0.70	
CDS tracking	0.92	
Neutron detection	0.23	
Data Acquisition	0.82	
NC solid angle	22 msr	
Decay mode/ Cross section [3]	Mode ID efficiency	Yield/10 days
$\pi^+\Sigma^-$/ 220 μb	0.2	750
$\pi^-\Sigma^+$/ 97 μb	0.07	120
$\pi^0\Sigma^0$/ 128 μb	0.015	33

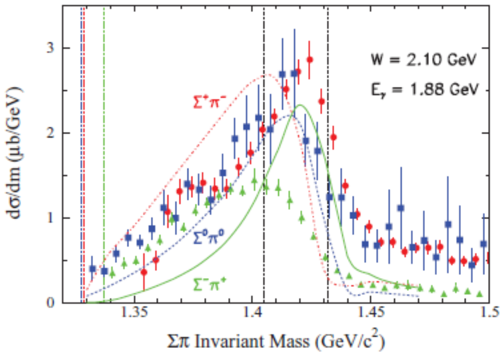

Fig. 1: Λ(1405) line shapes observed in the p(γ, K⁺)πΣ reactions reported by the CLAS collaboration. Figure is taken from Ref. [5]. See Ref. [5] for details.

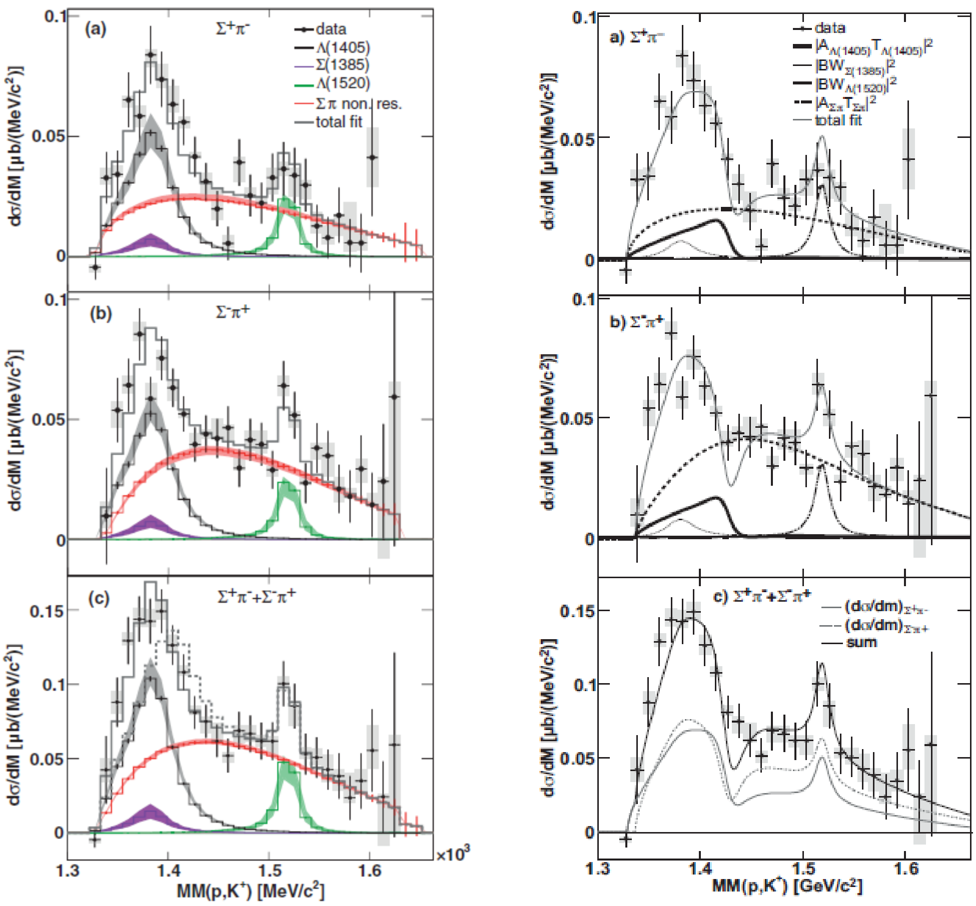

Fig. 2: (left) Missing mass spectra of the $pp \to pK^+\pi^\mp\Sigma^\pm$ reactions reported by the HADES collaboration [7]. (right) A theoretical interpretation of the observed spectra [9]. Figures are taken from Refs. [7,9].

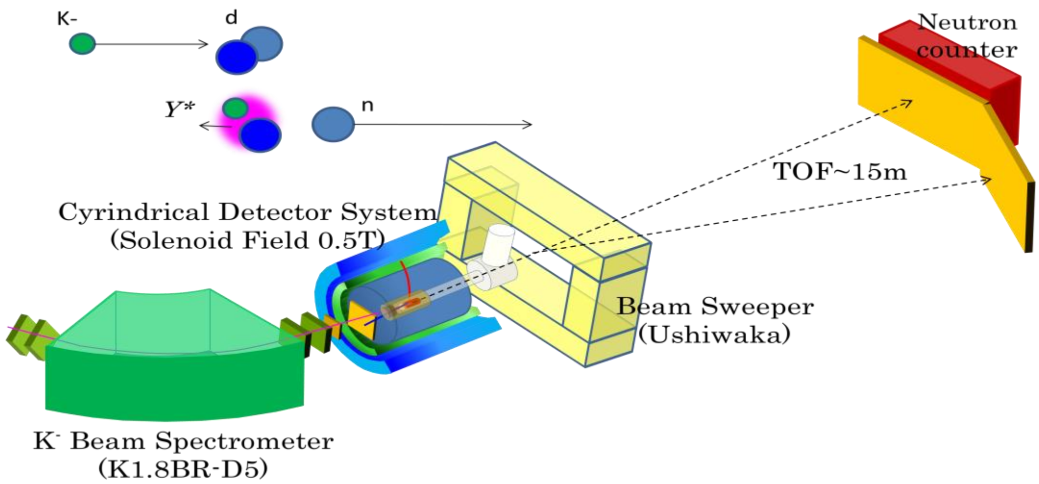

Fig. 3: Schematic layout of the E31 setup. A kaon beam at 1 GeV/c is irradiated on the deuteron target. A neutron is kicked at the forward angle to form Λ(1405).

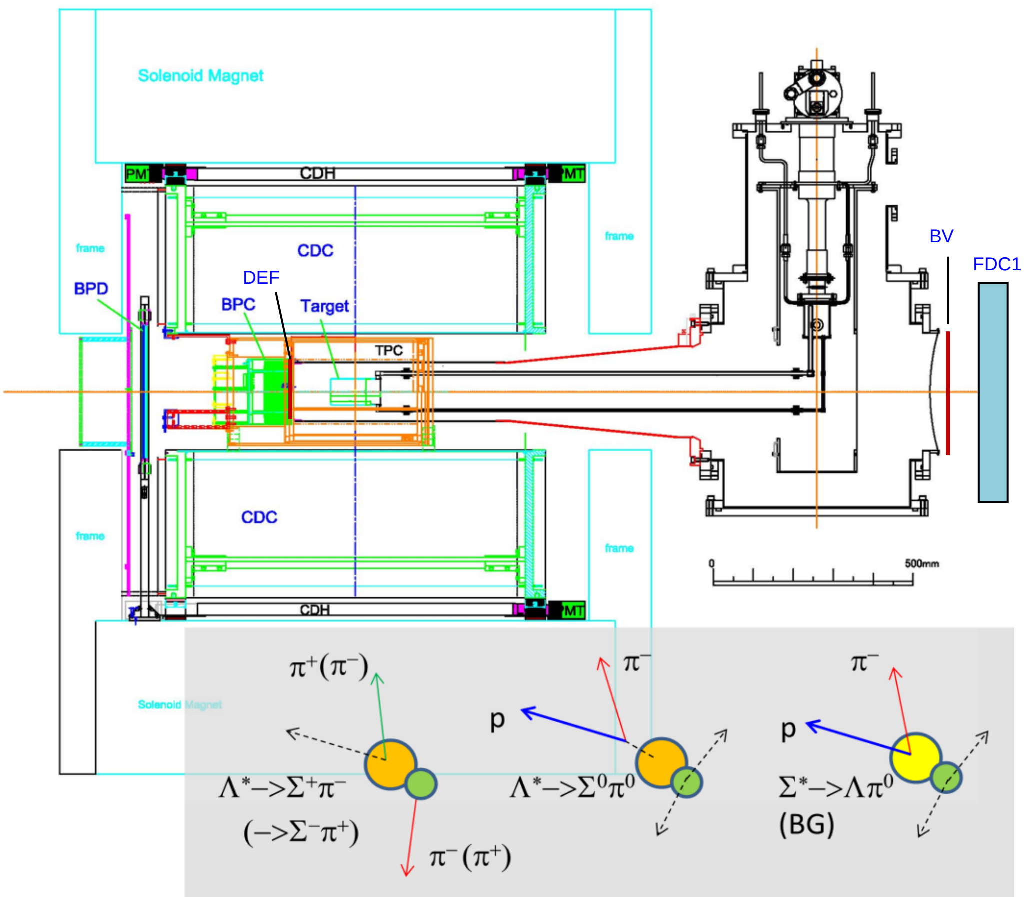

Fig. 4: Side view of the Cylindrical Detector System and the deuteron target. Typical decay topologies from produced hyperon resonances are also shown.

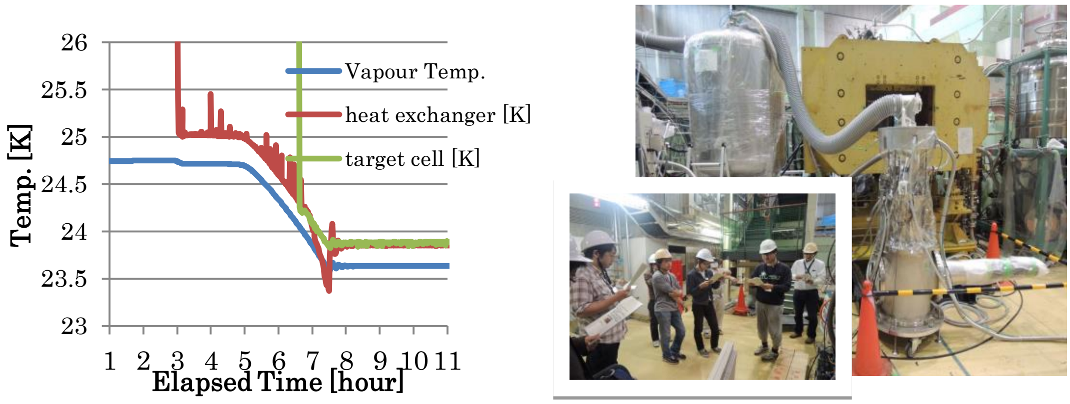

Fig. 5: .Successful liquefaction of the D2 target was made at the K1.8BR area. A lecture for safety operation of the liquid hydrogen (deuterium) target was carried out (inlet of the right photograph).