Letter of intent for a hadron spectroscopy experiment with RF-separated high energy $K^{\pm}$ beam at JHF

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1 Introduction

Hadron spectroscopy has been a very important subject in High Energy Physics starting from 60-es of the last century. Among many grate achievements one can mention the building-up and development of the concept of the SU(3) symmetry , discovery of the charm and bottom quarks, evidence for gluebals, hybrids, etc. Recently a new field of search for chiral particles such as a $\sigma(600)$ is opening. One could notice, that "typical" experiments in the $\pi^{\pm}$, and proton beams have accumulated huge amount of statistics and are limited mainly by the systematics and processing power. On the other hand, experiments in $K^{\pm}$ and $\bar{p}$ beams are statistically limited. The reason for that is obvious, a typical percentage of $K^{\pm}(\bar{p})$ in the secondary beams is $3 \div 5\%(\sim 0.5\%)$, and the total intensity of the beam normally cannot be increased above $5 \div 10 \times 10^{6}$ /spill because of a setup capability. That is why we consider spectroscopy in the $K^{\pm}(\bar{p})$ as a main goal of our proposal. The main subject of the physics program is a search and study of meson and baryon strange states and states with hidden strangeness. The expected mass of such objects is $\sim 1.5 \div 3.2$GeV , which corresponds to the threshold beam momentum of $\sim 5 \div 8$GeV depending on the specific production process. That is why we consider $P \sim 12$ GeV as an optimal beam momentum.

2 The beam

If one looks at current (or recent) experiments with charged kaons, quite some with unseparated beams of different energies and intensities can be found, few with very low energy electrostatic separated beams, but there is no high energy separated beams in operation. The reason is that the relatively simple electrostatic $E \times B$ separation, which is very effective at low energies does not work above ~ 6GeV and one has to build high power RF cavities which provide strong oscillating electrical field. The most popular Panofsky-Montague-Schnell scheme of separation is presented in Fig. 1. The beam with definite momentum is sent to the system of two deflectors

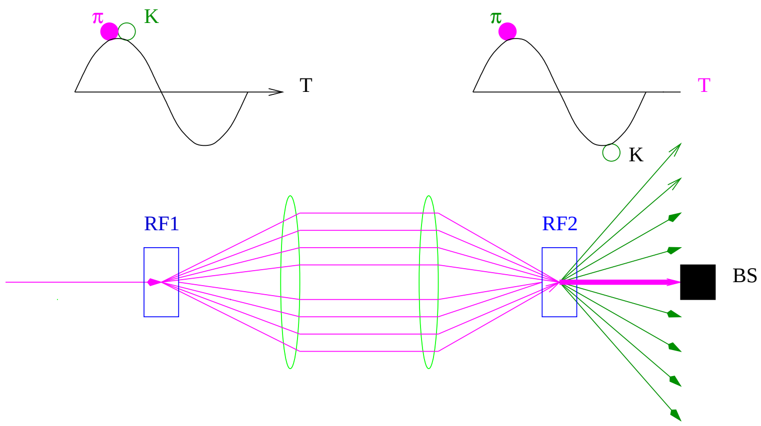

Figure 1: The principal scheme of RF separation.

with "-1" optics in between. The phase shift between two deflectors is tuned in such a way that the "unwanted" particles (π in Fig. 1) have equal relative phase in both deflectors. As a result, they get two deflections which, in the presented scheme, compensate each other and are absorbed in the beam stopper. The distance between the deflectors is selected in such a way that kaons, because of longer time-of-flight, have 180° shift with respect to pions, get double deflection and avoid the absorber (it is interesting to note that because of random relation $\frac{m_p^2-m_\pi^2}{m_K^2-m_\pi^2} \sim 4$, the protons are suppressed "for free" together with pions).

The RF deflectors must be superconductive to be able to keep the field during slow extraction time of few seconds. Moreover, to get high quality factor of cavities it is necessary to cool them down to the super-fluid He temperature of 1.8 K°. All these aspects make the design technologically complicated.

At present, there are two projects which aim to build RF-separated high intensity (slow extracted) beams:

1. FNAL Main Injector superconducting RF-separated beam for the CKM experiment [1].
2. IHEP, Protvino U-70 PS superconducting RF-separated beam for the "OKA" experiment, based on existing Karlsruhe-CERN superconductive deflectors [2].

CKM project is mainly devoted to a very high luminosity experiment to measure $K^+ \to \pi^+\nu\bar{\nu}$ decay. "OKA" project in which many of the authors of the present proposal are participating or are willing to participate is more similar to what we are going to propose for JHF. It is instructive to briefly remind the main parameters of the "OKA" project.

2.1 Beam for the "OKA" project

The main parameters of the "OKA" project beam are summarized in the Table 1. The basic

Table 1: The parameters of the RF-separated beam.

Target	50 cm Be
Primary proton beam energy	70 GeV
Primary proton beam intensity	10^{13} ppp
Duty cycle	2/9 sec
Spill/h	4×10^2
Secondary beam momentum	12.5 GeV
Δp/p %	± 4
Horizontal acceptance	± 10 mrad
Vertical acceptance	± 1.9 mrad
Length of the beam line	~ 200 m
Distance between separators	76.3 m
Intensity of $K^+(K^-)$ at the end	$4(1.3) \times 10^6$
π^+, p contamination	$< 50\%$
Muon halo	$< 100\%$

working energy is 12.5 GeV, it is limited by the space available in the U-70 gallery. The second

working point of 18 GeV corresponds to the condition of 360° shift between π and p and is supposed to be used for the hadron spectroscopy in the kaon beam.
The intensity of the beam is limited by the relatively low deflection field in the cavities ($\sim$1.2 MeV/m).

2.2 Main requirements for the JHF extracted proton beam for the RF-separated beam

The following requirements for the RF-JHF beam can be put forward:

1. The kaon beam momentum $\sim$ 12GeV/c
2. The kaon beam intensity $\sim 5 \times 10^6$/spill

As a consequance, using similar design of the "OKA" beam:

1. The required intensity of the slow extracted proton beam is $\sim 10^{13}$ppp
2. The length of the RF kaon beam line from the target to the setup is not less than 100 m.
3. Superconductive RF separator is the essential part of the beam line. As a consequence, a Liquid Helium plant, which is capable to provide super-fluid Liquid Helium with the temperature of 1.8 K with a power of $\sim$ 50Wt at this temperature is necessary.
   In Protvino project the intensity of the secondary kaon beam is mainly defined(limited) by relatively low deflection field of the cavities. If modern RF separators will be built, the requirement for the proton beam intensity could be relaxed by several times.

3 A sketch of the physics program

Let's start a brief review of a possible fix-target program with the separated $K^{\pm}$:
Old SLAC LASS experiment, which used separated K^-beam with the energy of 11 GeV [3] reached $\sim 4.1 ev/nb$ integrated sensitivity. After many years of operation, main IHEP, Protvino spectroscopic experiments VES and GAMS-4pi, which have been working in non-separated beams have reached similar sensitivity.
A modern experiment in RF-separated beam in 3 month can get $\sim$ 500 ev/nb. The following experiments can be performed with this sensitivity:

1. Search for exotic states with hidden strangeness.
   F.Close and P.Page [4] predict $s\bar{s}g$ hybrid with $J^{PC} = 2^{-+}$ Γ=120 MeV with the main decay mode into $K_2^*(1430)K$; $K_1(1270)K$.
   RF-JHF can look for this state in the reaction $K^-p \to K^+K^-\pi^0\Lambda$
2. Search for 5-quark states $uuss\bar{s}$:
   CERN (2m) and Argone (15 ft) bubble chambers saw narrow ($\Gamma <$ 20MeV) $\Sigma(3170)$ state in the reaction $K^-p \to Y^{*+} + \pi^-$; [5], with $Y^{*+} \to \Sigma K\bar{K} + 2\pi$; $P_K = 8.25; 6.5$ GeV . This state needs confirmation.

3. Spectroscopy and Decays of light mesons with hidden strangeness.
   One of an interesting subject is to study , in analogy with the charmonium system a similar $s\bar{s}$ system, which we call "strangeonium". The most well known members of this family is $\phi(1020)$ and $f_2(1515)$. $f_1(1285)$ and $f_0(400-1200)$ can , as well, have "strangeonium" admixture. The states can be produced in the reactions $K^-p \rightarrow f + \Lambda$. One of the ways to study the "strangeonium" system is to measure branchings for the radiative decays of the type $f_2(1515) \rightarrow \phi\gamma$
   The only discovered transition of this type is $f_1(1285) \rightarrow \phi\gamma$ [7].

4. Primakoff physics.
   In a recent publication R.Rogalyov(IHEP) [6] the cross-sections of the processes $K^+Z \rightarrow K^+\pi^0 Z$ and $K^+Z \rightarrow K^0\pi^+Z$ are compared. In the first process there is a contribution of Wess-Zumino-Witten(WZW) anomaly to the $KK\pi\gamma$ vertex. As a result, the predicted ratio of the cros-sections of the processes σ_1/σ_2 is about 80 nb/ 15 nb near the threshold. Nobody tested WZW with s-quarks .
   Measurement of the "polarizability" of K in the process $K^+Z \rightarrow K^+\gamma Z$ is also of interest.

5. Search and study of chiral particles of $\sigma(600)$, $\kappa(900)$ etc.
   We are confronting with difficulties in classification of mesons in the low mass region. Too many states are found to be assigned as members of a relevant SU(3) nonet. In particular, a scalar nonet has had difficulty for many past years. Recently a new isoscalar scalar state has been found in the low mass region around 600 MeV[8, 9, 10], which is listed as $\sigma(600)$ in the PDG table of 2002[11]. It is natural that this scalar state is considered as a chiral partner of pseudoscalar π [12, 10]. The $\sigma(600)$ is found in production processes[14] such as pp central production[8], J/Ψ decays[9] and others[10]. Existence of σ has been also confirmed in the reanalysis of the $\pi\pi$ scattering process[13]. Recently, a new scalar state with strangeness has been reported around 900 MeV in D* decays[15]. This can be considered to be a candidate of members of the chiral nonet 0^{++}. A new field of search and study of chiral particles is open.

4 Proposed strategy for the development of the beam

As it is seen from above, the proposed experimental program puts forward a very tight requirements for the intensity and infrastructure of the beam line. It is obvious, that this kind of beam can be only realized at the second stage of JHF project. We propose to establish a strong collaboration between the RF-JHF and OKA projects. The experience which we get from OKA would allow to continue the research with better setup, better beam and more beam-time. Most of necessary apparatus and detectors for the experiment can be supplied by both Japanese and Russian sides. The BENKEI magnet can be used as a spectrometer magnet. Even at the first stage of the JHF project, a part of the above physics can be done with a normal high momentum beam.

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