# Letter of Intent to J-PARC PAC for Study of Parton Distribution Function of Mesons via Drell-Yan Process at J-PARC at High-p beamline

S. Sawada
*High Energy Accelerator Research Organization*
*Ibaraki 305-0801 Japan*

J.-K. Ahn
*Department of Physics*
*Pusan National University*
*Pusan 609-735 Korea*

H.-C. Bhang, Seonho Choi (Spokesperson, contact)
*Department of Physics and Astronomy*
*Seoul National University*
*Seoul 151-747 Korea*

Contact: Seonho Choi (choi@phya.snu.ac.kr)

April 28, 2006

**Abstract**

We propose a comprehensive measurement of cross sections of Drell-Yan processes using high energy meson beams and hadron targets. Drell-Yan process between mesons and hadrons has been a major source of information on the quark structure function of mesons. At J-PARC, we are particularly interested in Drell-Yan process with high energy, high intensity Kaon beams. We would like to start the program with high statistics cross section measurements for $\pi^- p$ and $K^- p$ reactions to study the modification of $\bar{u}$ quark structure function when its companion changes from $d$ quark to heavier $s$ quark. Once completed, the program will provide a valuable information on structure functions of mesons for which the theoretical calculation should be easier than those of baryons.

# 1 Introducion and Motivation

Historically, the parton distributions functions (quark distributions or structure functions) have been measured precisely for the baryons using high energy electron beams. The experimental results using both unpolarized or polarized electron beams produced a wealth of information on the internal structure of protons and neutrons which has become one of the key evidences to support Quantum-Chromo Dynamics(QCD). However, limitations exist for the electron beam scattering experiments. The most significant constraint is the necessity of stable target, which excludes most of the hadrons except the proton and the neutron (via deutron target).

In this respect, Drell-Yan process between hadrons provide a new way to probe quark and *anti*-quark distributions inside hadrons. Especially, the Drell-Yan process between mesons and hadrons provide an almost unique tool to study quark structure functions of mesons.

Earlier experiments using meson beams have been focused on pion beams which had sufficient intensity as secondary beams. Early experiments at CERN and Fermi Lab has determined pion structure functions from Drell-Yan process with secondary pion beams.[1, 2, 3] The same technique can be easily applied to kaon beams to probe kaon structure functions, as discussed by several authors.[4, 5] However, experiments with kaon beams had major difficulty in accumulating sufficient statistics due to limited beam intensity at times. One of the pioneering experiment from NA3 has compared cross sections of dimuon production from $\pi^- + p$ and $K^- + p$ reactions.[6] From the experiment, they were able to deduce the difference of $\bar{u}$ distribution function in pions and kaons. As a partner to $\bar{u}$, pions have $d$ quark while kaons have $s$ quark, which is heavier. Although the experiment has shown a clear trend that the $\bar{u}$ distribution function deviates for both mesons at large $x$ region, the measurement is subject to large uncertainties due to the limited statistics of the experiment and several assumptions made in the extraction of the $\bar{u}_K/\bar{u}_\pi$ ratio.

Recently, it has been indicated[7, 8] that Drell-Yan process with kaon beams can be used to resolve the violation of the Gottfried sum rule measured by the New Muon Collaboration (NMC) and Fermi Lab E866 Collaboration.[9, 10, 11, 12] This violation means $\bar{d} - \bar{u}$ and $\bar{d}/\bar{u}$ asymmetries in the nucleon sea. Especially, the authors of [7] emphasizes that intense $K^+$ beams can provide more efficient measurement of $\bar{d}^p(x) - \bar{u}^p(x)$.

The use of high energy, high intensity kaon beams with nucleon targets

will be able to provide a unique opportunity to study kaon structure functions and anti-quark distribution in the nucleons.

# 2 Experiment

The experiment can be carried out at J-PARC with high energy, high intensity secondary kaon and pion beams. Such high energy meson beams will be produced by placing a secondary target at 30 GeV proton beam available at High-p beamline. With a well-developed technique of momentum and mass selection, high energy, high intensity pion or kaon beams can be prepared. For detection of dimuon pairs ($\mu^+\mu^-$), similar detector designed for measurement of Drell-Yan process from $pN$ reactions can be used without any modifications.[13].

The experiment will measure cross sections of dimuon production from 8 different reactions using 4 different beams ($K^+$, $K^-$, $\pi^+$, $\pi^-$) and 2 different targets ($p$ and $d$). We propose to start with $K^-$ and $\pi^-$ beams on the proton target from which we can obtain $\bar{u}_K/\bar{u}_\pi$ ratio with improved statistics. If we apply the method described in [8], we can extract information about the kaon structure.

We plan to use $K^-$ beam at 10 GeV, whose estimated intensity is $10^6$/pulse with 30 GeV primary proton beam. This kaon energy with proton target corresponds to center of mass energy $s \simeq 20$ GeV$^2$ and the mass of the produced muon pair will be 2 to 3 GeV. ($2 \leq M_{\mu\mu} \leq 3$). These kinematic condition will cover $x$ range of quark/anti-quark from about 0.3 to 0.7.

# 3 Conclusion

The high energy, high intensity meson beams at J-PARC will make it possible to have a comprehensive measurement of cross sections of Drell-Yan processes between mesons and nucleon targets. Especially, high intensity kaon beams at J-PARC will provide a new window to study structure functions of mesons and anti-quark distribution in nucleons. With a complete set of measurements, the result at J-PARC will provide a unique information on the structure functions of mesons.

# References


[1] J. Badier *et al.*, Z. Phys. C **18**, 281 (1983).

[2] M. Bonesini *et al.*, Z. Phys. C **37**, 538 (1988).

[3] J.-S. Conway *et al.*, Phys. Rev. D **39**, 92 (1989).

[4] R.-G. Badalyan and G.-R. Gulkanyan, Sov. J. Nucl. Phys. **50**, 115 (1989).

[5] N.-N. Badalyan, R.-G. Badalyan and H.-R. Gulkanyan, Z. Phys. C **42**, 69 (1989).

[6] J. Badier *et al.*, Phys. Lett. **93B**, 354 (1980).

[7] R.-S. Bhalerao and J.-T. Londergan, Phys. Rev. D **57**, 3065 (1998).

[8] C. Avila, J.-C. Sanabria and J. Magnin, Phy. Rev. D **66** 034016 (2002).

[9] P. Amaudruz *et al.*, Phys. Rev. Lett. **66**, 2712 (1991).

[10] M. Arneodo *et al.*, Phys. Rev. D **50**, R1 (1994).

[11] E.-A. Hawker *et al.*, Phys. Rev. Lett. **80**, 3715 (1998).

[12] J.-C. Peng *et al.*, Phys. Rev. D **58**, 092004 (1998).

[13] J-PARC Letter of Intent, *Physics of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron*, S. Sawada and J.-C. Peng, spokespersons.