Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron

J-PARC Proposal P04 PAC, June 30 – July 2, 2006

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Collaboration

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Physics with High-Mass Dimuons at J-PARC

Drell-Yan (at 50 GeV):

- $\overline{d} / \overline{u}$ flavor asymmetry at large x
- Antiquark distributions in nuclei
- Quark energy loss in nuclei
- J/Ψ Production (at 30 or 50 GeV):
- J/Ψ nuclear dependence
- $\overline{d} / \overline{u}$ via J / Ψ production

Spin physics with dimuons (mostly with polarized beam/target):

• Drell-Yan with polarized beam/target

(Sivers parton distributions, sea-quark polarizations)

• J/Ψ with polarized beam/target

(Gluon polarization, gluon sivers function)

• Unpolarized Drell-Yan decay angular distributions (Boer-Mulder's distribution function)



Deep-Inelastic Scattering versus Drell-Yan

Drell-Yan cross sections are well described by NLO calculations

Dimuon Spectrometer for FNAL E605/772/789/866



 $p + p(d) \rightarrow \mu^+ \mu^- x \quad at \ 800 \ GeV/c$



Two components in the $\mu+\mu$ - spectrum:

(a) Continuum: Drell-Yan process

(b) Vector mesons: J/ψ , Y

$\overline{d} / \overline{u} \text{ flavor asymmetry from Drell-Yan}$ $\left(\frac{d^2\sigma}{dx_1 dx_2}\right)_{D,Y_1} = \frac{4\pi\alpha^2}{9sx_1 x_2} \sum_{a} e_a^2 \left[q_a(x_1)\overline{q}_a(x_2) + \overline{q}_a(x_1)q_a(x_2)\right]$



Models for $\overline{d} / \overline{u}$ asymmetry



Theses models also have implications on

• asymmetry between s(x) and $\overline{s}(x)$

 flavor structure of the polarized sea
 Meson cloud has significant contributions to sea-quark distributions

Comparison with models



Most models can explain $d - \overline{u}$ No model can describe $\overline{d} / \overline{u}$ at large x

$\overline{d} / \overline{u}$ and \overline{u} at large x using 50-GeV proton beam $\frac{d\sigma_{DY}}{dx_1 dx_2} = \frac{1}{s}$ at fixed x_1, x_2

DY cross section is 16 times larger at 50 GeV than at 800 GeV



 10^{12} protons per spill (3 s) 50-cm long LH_2 / LD_2 targets 60-day runs for each targets assuming 50% efficiency

p + p D-Y at 50 GeV also directly measure \overline{u} at large x

Modification of Parton Distributions in Nuclei



F₂ contains contributions from quarks and antiquarks

How are the antiquark distributions modified in nuclei?

Modification of Antiquark Distributions in Nuclei

Nuclear dependence of Drell-Yan



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Sensitive to \overline{u} distribution in nuclei

Quark Bremsstrahlung in Nuclear Medium

- Landau-Pomeranchuk-Migdal (LPM) effect of medium modification for electron bremsstralung has been observed
- LPM effect in QCD remains to be identified
- Quark energy loss ΔE is predicted to be proportional to L², where L is the length of the medium
- Enhanced quark energy loss in traversing quark-gluon plasma



Quark energy loss in cold nuclei needs to be better measured



Quark Energy Loss with D-Y at 50 GeV

Fractional energy loss is larger at 50 GeV

Possible to test the predicted L²-dependence from the A-dependence measurement



J/Ψ Production at 30 GeV



J/Ψ production at 30 GeV is sensitive to quark and antiquark distributions

Nuclear Dependence of J/Ψ Production at 30 GeV



30 GeV data would provide crucial test for the x_F -scaling in J/ψ production

Determination of $\overline{d} / \overline{u}$ Asymmetry via J / Ψ Production at 30 GeV



 $\sigma(p+d \rightarrow J/\Psi)/\sigma(p+p \rightarrow J/\Psi)$ is sensitive to $\overline{d}/\overline{u}$

Spin contents of the proton

- Origin of the nucleon spin 1/2 ? ⁺/₂ - ⁺/₂ -
 - polarized DIS experiments showed the quark-spin contribution is only 10-30%
 - gluon-spin contribution ?
 - Semi-inclusive SID at DESY and CERN
 - polarized p-p collision at BNL/RHIC



Small Δg implies significant contribution from L ₁₈

Single-spin asymmetry in polarized p-p collision

• Orbital angular momentum

 Large single-spin asymmetry in meson production in polarized p-p: Sivers, Collins, and/or higher-twist effect?



RHIC-STAR √s = 200 GeV



- Why Drell-Yan?
 - A simple process in hadron reactions
 - No final-state effect \rightarrow no Collins effect
- Why J-PARC?
 - Polarized beam feasible
 - High luminosity (L= $2x10^{36}/cm^{2}/sec$)

$$A_{N}^{DY} = \frac{\sum_{q} e_{q}^{2} f_{1T}^{\perp}(x_{q}) f_{\overline{q}}(x_{\overline{q}})}{\sum_{q} e_{q}^{2} f_{q}(x_{q}) f_{\overline{q}}(x_{\overline{q}})}$$

Spin physics with dimuons at J-PARC

Single-spin asymmetry (A_N) measurements for orbital angular momentum

- Drell-Yan, J/Ψ
- Open-geometry apparatus: D-meson, χ_c , etc.



Drell-Yan A_N (Ji et al.)

-sensitive to Sivers effect at low $q_T \ll Q$ -sensitive to higher-twist effect at high $q_T \sim Q$

-Sivers function in Drell-Yan is expected to have a sign opposite to that in DIS.



Other measurements

- Drell-Yan A_{LL} for sea-quark polarization
- Drell-Yan A_{TT} for transversity
- Unpolarized Drell-Yan for Boer-Mulders function
- A_{LL} for J/ Ψ for gluon polarization $_{20}$

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Schematic View in the Horizontal Plane



- Two vertically bending magnets with PT kick of 2.47 GeV/c and 0.5 GeV/c
- A tappered copper beam dump and Cu/C absorbers in the first magnet
- Tracking is provided by three stations of MWPCs and drift chambers
- Station 4 provides muon identification and tracking
- 2 x 10¹² 50 GeV protons/spill is requested

Simulation of Detector Acceptance

Expected Drell-Yan counts for a two-month p+d run at 50 GeV



- 10¹² protons/spill
- 50-cm long liquid deuterium target
- Assume 50 percent efficiency

Simulation of Detector Resolutions

Expected resolutions for Drell-Yan events



Summary

- We propose to study high-mass dimuon production at J-PARC with a high-rate spectrometer.
- A rich physics program in Drell-Yan and J/Ψ production can be pursued at J-PARC.
- 50 GeV proton beam with 10¹² protons per spill is requested.
- 30 GeV proton beam would also be interesting for studying the J/ Ψ production.
- An extensive program in spin physics can be pursued using this spectrometer together with polarized beam/target in the future.

Connection with Fermilab E906

- Status of E906
 - Approved by Fermilab PAC in 2001
 - Waiting for ~2 million dollars equipment fund from DOE
- If E906 will be performed
 - First data will be taken around 2010
 - Future at Fermilab is uncertain
 - E906 measurements should be verified and extended at J-PARC. Spin is unique at J-PARC
- If E906 is not performed
 - J-PARC will be the only facility for such measurements
 - Cost of the experiment would be higher