SSA Measurements with Primary Beam at J-PARC

Joint UNM/RBRC Workshop on “Orbital Angular Momentum” in Albuquerque
February 25th, 2006
Yuji Goto (RIKEN/RBRC)
Outline

• Introduction
  – J-PARC
  – spin physics with primary beam at J-PARC
• Drell-Yan experiment
• SSA measurements
• Summary
J-PARC at Tokai

KAMIOKA

295 km

1 hour

NARITA

TOKYO

KEK

Tsukuba

JAERI

JAEA

Tokai
J-PARC facility

Materials and Life Science Experimental Facility

Hadron Beam Facility

Nuclear Transmutation

Neutrino to Kamiokande

Linac (330m)

3 GeV Synchrotron (25 Hz, 1MW)

50 GeV Synchrotron (0.75 MW)

J-PARC = Japan Proton Accelerator Research Complex

Joint Project between KEK and JAEA
J-PARC facility

- The budget for about 2/3 of the entire project has been approved by the Japanese government from JFY2001 as Phase 1
- Phase 1 consists of major accelerator components and a part of experimental facilities

![Diagram of J-PARC facility]
# J-PARC parameters

– numbers in parentheses are for the phase 1

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<th>Parameter</th>
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<td>(2x10^{14} ppp, 9 mA)</td>
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**J-PARC schedule**

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Call for proposals started: deadline April 28, 2006

First beam for the nuclear-particle experiments in JFY2008

First beam for the neutrino experiments in JFY2009
J-PARC facility

September, 2005

Hadron Experimental Facility

Number of Users: about 600
(about 1/3 from Japan)
Hadron experimental hall (phase 1)

beamlines for secondary beam experiments at the beginning of the phase 1

Experimental Area

A-Line

Test Beam

K1.8BR

K1.8

K1.1/0.8 (S-type)

K1.1/0.8 (C-type)

area for primary beam experiments

Beam Dump

(on the guide rail for Phase 2)
**Introduction**

- **Origin of the nucleon spin 1/2?**
  \[
  \frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta g + L
  \]
  - polarized DIS experiments showed the quark-spin contribution is only 10-30%
  - gluon-spin contribution?
  - orbital angular momentum?

- **Scaling violation in polarized DIS**
  
  SMC: \( \Delta g(Q^2 = 1 \text{ GeV}^2) = 0.99^{+1.17}_{-0.31} \text{(stat)}^{+0.42}_{-0.22} \text{(syst)}^{+1.43}_{-0.45} \text{(th)} \)
  
  
  E155: \( \Delta g(Q^2 = 5 \text{ GeV}^2) = 1.6 \pm 0.8 \text{(stat)} \pm 1.1 \text{(syst)} \)
  
Introduction

• Semi-inclusive DIS
  – high-$p_T$ hadron pairs
  – open charm production

COMPASS high $p_T$ hadron pairs
($Q^2 < 1\text{(GeV/c)}^2$)
$\Delta G/G = 0.024 \pm 0.089\text{(stat)} \pm 0.057\text{(syst)}$
at $x_g = 0.095 (\mu^2 \sim 3\text{(GeV/c)}^2)$
**Introduction**

- Present target at RHIC – gluon-spin contribution
  - polarized hadron collision
  - leading-order gluon measurement

![Diagram](image)

- Direct photon production
- Heavy-flavor production
Introduction

- Gluon contribution – PHENIX $A_{LL}$ of $\pi^0$

  - PHENIX official statement
    - conclusively excludes GRSV maximal scenario
    - consistent with GRSV standard and GRSV $\Delta g=0$ input scenarios

  - Personal statement
    - $\sim$1-sigma region: $\Delta g < 0.4$
    - orbital angular momentum measurements should be developed for the final solution

GRSV-max: $\Delta g = 1.84$

GRSV-std: $\Delta g = 0.42$

at $Q^2=1(\text{GeV}/c)^2$

best fit to DIS data
**Introduction**

- **Orbital angular momentum**
  - hint in hadron reactions

Fermilab E704: $E_{\text{lab}} = 200$ GeV

STAR at RHIC: $\sqrt{s} = 200$ GeV

- asymmetries in angular distribution of semi-inclusive hadron production at polarized DIS exps
Drell-Yan experiment

- Fermilab E866/NuSea and E906 at MI
  - closed geometry

Fermilab $E_{lab} = 800$ GeV
$2 \times 10^{12}$ protons / 20 sec
Drell-Yan experiment

- Ratio of p+d cross section to p+p ↔ d-bar/u-bar

CTEQ4M
CTEQ5M
GRV98
MRST

"CTEQ4M (d - u = 0)"

FNAL E866/NuSea Drell-Yan

sigma_{pd}/sigma_{pp}

E866 Data 800 GeV
Main Injector 120 GeV
JHF 50 GeV

1% Systematic error not shown
**Experimental apparatus**

- Two vertically bending magnets with $p_T$ kick of 2.47 GeV/c and 0.5 GeV/c
- Closed geometry
- Tracking is provided by three stations of MWPC and drift chambers
- Muon ID and tracking are provided
- $2 \times 10^{12}$ 50 GeV p/spill
- Based on the Fermilab spectrometer for 800 GeV, the length can be reduced but the aperture has to be increased

**Schematic view in horizontal plane**

Tapered copper beam dump and Cu/C absorbers placed within the first magnet
Simulation studies

- Expected Drell-Yan counts for a two-month p+d run at 50 GeV
  - $2 \times 10^{12}$ protons/spill
  - 50-cm long liquid deuterium target
  - assume 50 percent overall efficiency
Possible layout of the hadron hall
**Drell-Yan experiment**

- \( A_{LL} \rightarrow \) sea quark polarization

![Diagram showing chiral quark soliton model prediction and 120-day run results](image)
SSA on Drell-Yan

- no final-state effect
- sensitive to Sivers effect at low $q_T$: $q_T \ll Q$

![Graph of Drell-Yan $A_N$ at JPAC Energy](image)

Sivers function fit from Vogelsang & Yuan: PRD 72, 054028 (2005).
(from Xiangdong Ji’s slide at J-PARC hadron structure workshop at KEK, December, 2005)
SSA on Drell-Yan

– sensitive to higher-twist effect at high $q_T$: $\Lambda_{QCD} \ll q_T$

(from Xiangdong Ji’s slide at J-PARC hadron structure workshop at KEK, December, 2005)
SSA measurement of pions

- Forward pions with a polarized target
  - backward $A_N(x_F < 0)$
  - sensitive to the gluon Sivers effect at fixed-target exp. energies
  - not very sensitive at collider energies

$E_{lab} = 200 \text{ GeV } \sqrt{s} = 19.4 \text{ GeV}$

RHIC: $\sqrt{s} = 200 \text{ GeV}$

SSA measurement of pions

- **Forward pions with a polarized target**
  - start with simple forward spectrometer with some particle-ID detectors
  - EM calorimeter for $\pi^0$

- **Forward pions with a polarized beam**
  - forward $A_N(x_F > 0)$
  - confirmation of E704 asymmetries at smaller energies
    - BNL-E925 at $E_{lab} = 22$ GeV confirmed for charged pions
    - $p_T$ dependence will give more information
SSA measurement of D-mesons

- gluon fusion or quark-pair annihilation
- no single-spin transfer to the final state
- sensitive to initial state effect: Sivers effect
  - to be measured at RHIC: PHENIX with silicon upgrade (2009)
- collider energies: gluon-fusion dominant
  - sensitive to gluon Sivers effect
- fixed-target energies: quark-pair annihilation dominant
  - sensitive to quark Sivers effect
- complementary

J-PARC: $E_{lab} = 50$ GeV

RHIC: $\sqrt{s} = 200$ GeV

D-meson

– cross section

• PYTHIA (6.228) study with PHENIX tune ($\langle k_T \rangle = 1.5 \text{ GeV}/c$, $M_c = 1.25 \text{ GeV}/c^2$, K-factor = 3.5, $Q^2 = s$)

• J-PARC: 3-4 order smaller cross section than that at RHIC
  – can be compensated by higher intensity/luminosity at J-PARC?
**D-meson**

- silicon detectors to identify second decay vertex
- yield study
  - $10^9$ proton/sec beam
  - 10% target
  - $2 \times 10^{33}$ cm$^{-2}$sec$^{-1}$
  - $\times$ 1 week = $10^3$ pb$^{-1}$
  - acceptance 0.05 – 0.3 to cover forward/mid-rapidity/backward

\[
\begin{align*}
D^0 \text{ yield} \\
1.5 \text{ GeV/c}
\end{align*}
\]

\[
\begin{align*}
p_T > 1.5 \text{ GeV/c} \\
5.5 \times 10^6 D^0 \text{ for } 10^3 \text{ pb}^{-1}
\end{align*}
\]
D-meson

- efficiency study necessary
  - decay
  - DCA cut efficiency
- detector study necessary
  - radiation hardness
  - D-meson identification: $\Delta E/E$ in silicon?
  - triggering
- beam intensity / luminosity as high as possible
  - depending on radiation hardness of detectors, occupancy/multi-collision capability, etc.
Other SSA measurements

• Charmonium
  – $J/\psi$ and $\chi_c$

• The most forward neutron
  – found at RHIC $\sqrt{s} = 200$ GeV
  – zero-degree calorimeter
  – large asymmetries in collider energies
    • $A_N \sim -12\%$ at $x_F > 0.2$ and $p_T < 0.3$ GeV/$c$ at RHIC
  – physics implication?
Other subjects

• Gluon polarization at large-$x$
  – charmonium $A_{LL}$
    • $J/\psi$, $\chi_{c0}$, $\chi_{c1}$, $\chi_{c2}$
    • $\chi_{c2}$: gluon-fusion dominant
      – produced mainly from helicity $\pm 2$ state of the gluon fusion
      – sensitive to $\Delta g(x)$
    • identified measurement is possible only in the fixed-target experiments
      – low photon energy of $\chi_c \rightarrow \gamma + J/\psi$ decay
  – direct-photon $A_{LL}$

• Transversity
  – Drell-Yan $A_{TT}$

• “Fields” effect
  – Drell-Yan $A_{LL}(q_T)$
Under discussion

• Polarized proton acceleration
  – study group was formed
  – installation of Siberian snakes seems possible
  – technical note in preparation

• Polarized target

• More discussion consideration and R&D
  – Drell-Yan apparatus +
  – silicon detector
  – calorimeter
Detector

- NA60 spectrometer
  - example of silicon spectrometer + muon detector
  - charm-identification with muon-coincidence

CERN

$E_{\text{lab}} = 158$ GeV

$2 \times 10^9$ protons / 5 sec
Detector

• PHENIX upgrades
  – technically important
  – silicon pixel & strip (stripixel) 2008 installation
    • RIKEN/RBRC group is leading
  – Si/W calorimeter
    • RIKEN/RBRC group is participating and supporting
Summary

• For the spin physics program with primary beam at J-PARC, study group for the polarized proton acceleration and the physics experiment were formed, and discussions are underway.

• Measurement of the orbital angular momentum component in the nucleon is one of the most important goal of the spin physics program at J-PARC.

• Drell-Yan experiments are planned
  – SSA measurements of Drell-Yan, pions, D-mesons, etc.
  – gluon polarization at large-x, transversity, etc.

• Physics and detector studies are ongoing.

• Collaboration with many groups in the world is very important.