Measurement of Anti-Quark Polarization at PHENIX

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The measurement of the anti-quark polarization and its flavor decomposition is crucial in the study of the spin structure of the nucleon. The deep inelastic scattering of polarized lepton off polarized nucleon target is not sensitive to those, because photon couples only to electric charge squared. Because of this, the current study of the flavor structure of the quark/anti-quark polarization has to assume flavor SU(3) symmetry.

The parity violating asymmetry A_L for W production in polarized pp collision is very sensitive not only to helicity structure of the anti-quarks in the proton but also to the flavor structure of them. The asymmetry for W^+ production can be written as

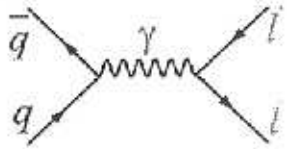
$$A_L^{W^+} = \frac{\Delta u(x_a, M_W^2)\bar{d}(x_b, M_W^2) - \Delta\bar{d}(x_a, M_W^2)u(x_b, M_W^2)}{u(x_a, M_W^2)\bar{d}(x_b, M_W^2) + \bar{d}(x_a, M_W^2)u(x_b, M_W^2)}$$

For W^- production, the u and d should be exchanged. Obviously the asymmetry is just the linear combination of the quark and anti-quark polarization. Furthermore, the flavor in the reaction is almost fixed. Thus flavor decomposition is possible.

In the PHENIX detector at RHIC, the production of W can be identified with the lepton with high transverse momentum such as p_T>20 GeV/c. With this experimental cut in the PHENIX Muon Arm, we expect about 5,000 events for each of W^+ and W^- productions with the integrated luminosity of 800 pb^{-1}. Reconstruction of partonic level kinematics is one of the key issues in the hadronic collisions. Using the correlation between muon momentum and x carried by the parton due to the decay angle distribution in V-A reaction, it is possible to extract the polarization as a function of x. The high momentum resolution expected from the detailed simulation and good muon identification proven in the beam test at KEK of the PHENIX detector system, will help this reconstruction very much.

Anti-quark Helicity Distribution

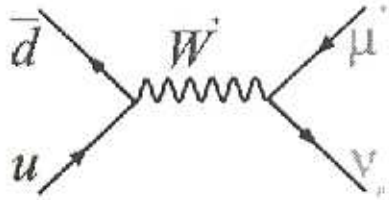
- Drell-Yan Production of lepton pairs



  - maximal parton level asymmetry: a_{LL}= -1
  - possible severe background from semi-leptonic decays of open charm productions $\sum_i e_i^2[\Delta q_i(x_a)\Delta\bar{q}_i(x_b)+(x_a \leftrightarrow x_b)]$

$$A_{LL} = -\frac{\sum_i e_i^2[\Delta q_i(x_a)\Delta\bar{q}_i(x_b)+(x_a \leftrightarrow x_b)]}{\sum_i e_i^2[q_i(x_a)\bar{q}_i(x_b)+(x_a \leftrightarrow x_b)]}$$

- W production
  - helicity of quarks definitely defined via V-A nature
  - flavor almost fixed: flavor analysis possible
  - PHENIX-Muon Arms, EMcal important



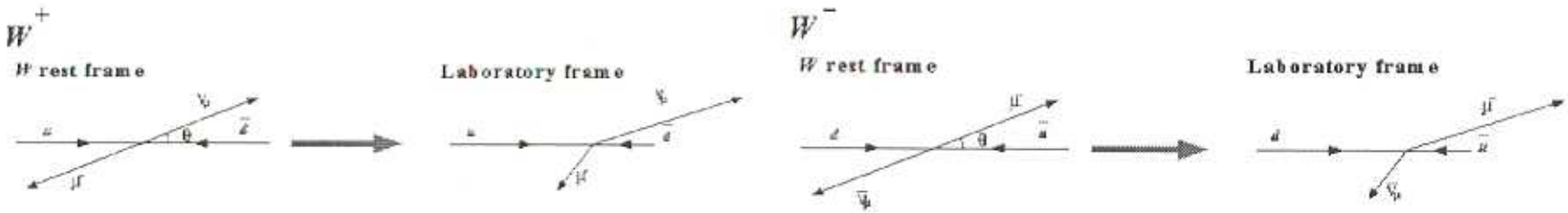
$$A_L^{W^+} = \frac{\Delta u(x_a, M_W^2)\bar{d}(x_b, M_W^2) - \Delta\bar{d}(x_a, M_W^2)u(x_b, M_W^2)}{u(x_a, M_W^2)\bar{d}(x_b, M_W^2) + \bar{d}(x_a, M_W^2)u(x_b, M_W^2)}$$

W yield with 800 pb^{-1}

PYTHIA w/ GRV94LO checked against CDF data

	W^-	W^+
acceptance for muon w/ $p_T > 20$ GeV/c	14%	4%
yield (both muon arms)	5100	5600
ΔA_L (statistical only)	2%	2%
rapidity average	0.78±0.34	0.71±0.41
background from Z-decay	1095(21.5%)	984(17.6%)

Acceptance difference between W^- and W^+



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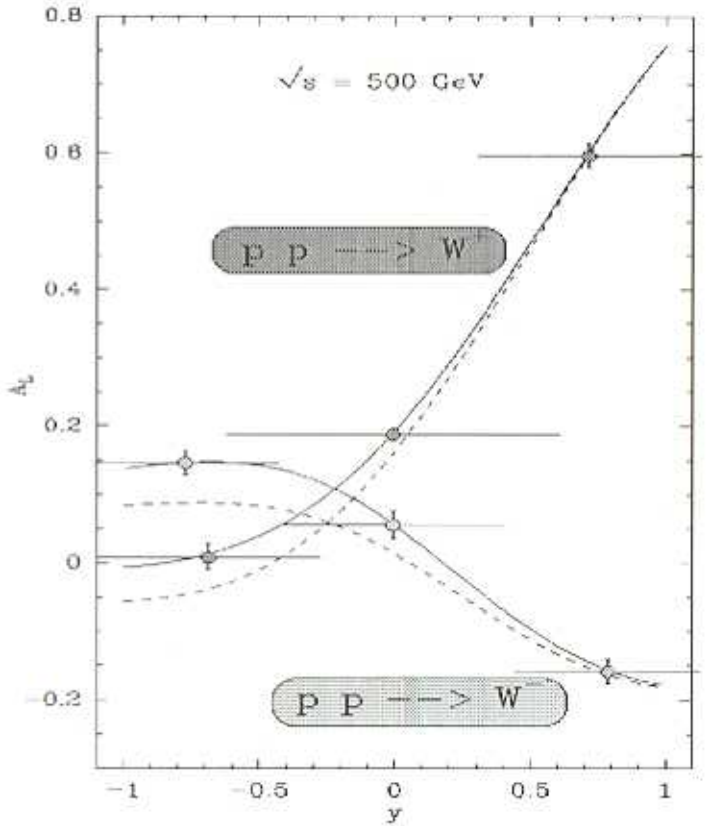
Prediction and Projected Error

- C. Bourrely, J. Soffer Published in Nucl.Phys.B445:341-379,1995

Prediction for the parity violating asymmetry A_L as a function of y^W

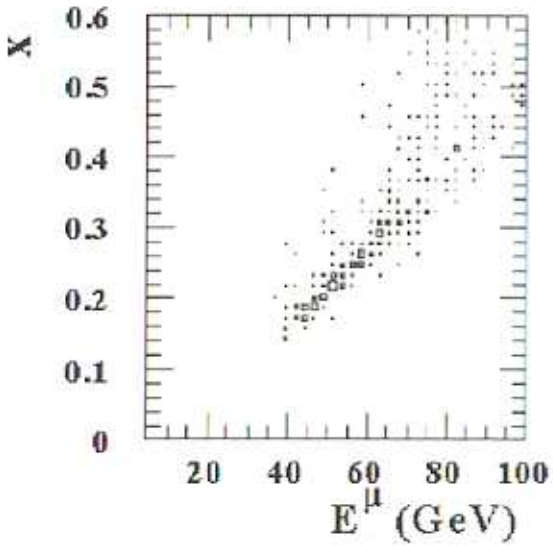
solid line: soft gluon
dashed line: hard gluon



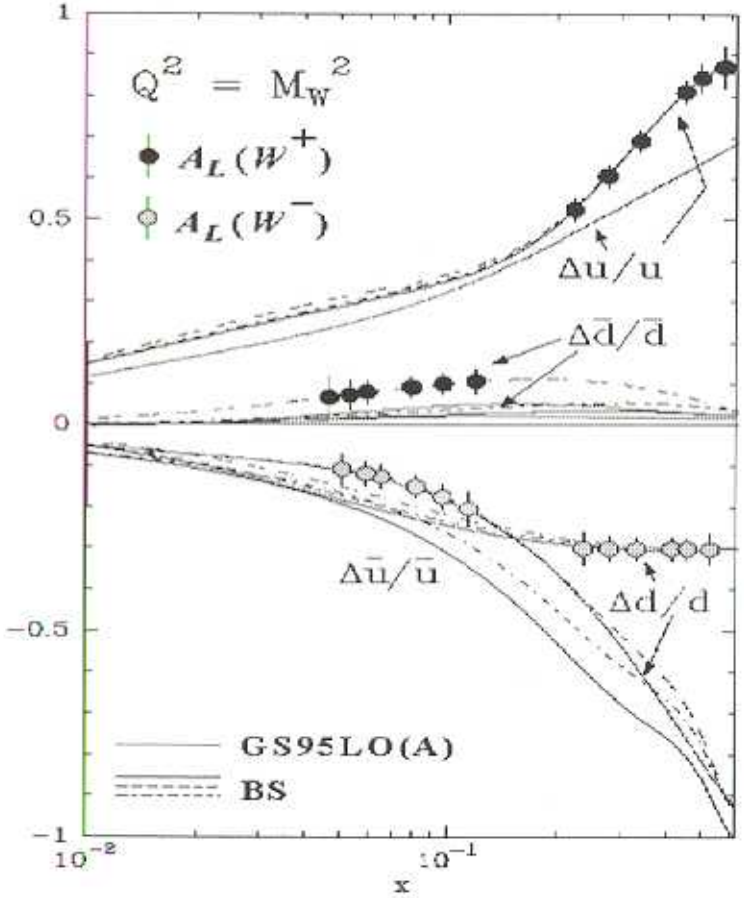
Parton Level Kinematics

- Decay ν cannot be detected: x-determination hard
- but good correlation x vs E^{μ} : V-A requires $(1+\cos\theta)^2$

$$p_{\mu} = \frac{\sqrt{s}}{4}\left[(1+\cos\theta)x_u + (1-\cos\theta)x_{\bar{d}}\right] M_W = \sqrt{x_u x_{\bar{d}} s}$$



p^{μ} region	x-average W^+
$34 < p^{\mu} < 50$ GeV/c	0.22±0.08
$50 < p^{\mu} < 60$ GeV/c	0.27±0.08
$60 < p^{\mu} < 70$ GeV/c	0.33±0.09
$70 < p^{\mu} < 80$ GeV/c	0.44±0.11
$80 < p^{\mu} < 95$ GeV/c	0.49±0.10
$95 < p^{\mu} < 120$ GeV/c	0.56±0.11

Sensitivity Goal - statistical limit

- Anti-quark polarization measured with A_L^W
- More systematic studies are underway
  - background from π/K decays
  - background from Z^0 decays