BNL-79146-2007
FORMAL REPORT

Proceedings of RIKEN BNL Research Center Workshop Volume 85

Parity-Violating Spin Asymmetries at RHIC-BNL

April 26 – 27, 2007

Organizers:

Matthias Perdekamp, Bernd Surrow and Werner Vogelsang

RIKEN BNL Research Center

Building 510A, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

CONTENTS

Preface to the Series..

Introduction and Overview
Organizers: W. Vogelsang, Matthias Perdekamp, Bernd Surrow i
Spin and W physics
J. Soffer.. 1
Models for the polarized nucleon sea
C. Weiss.. 9
Polarized protons in RHIC at 500 GeV
M. Bei.. 15
RHICBOS studies
P. Nadolky.. 21
Studies of hadronic W decays at RHIC
S. Arnold.. 29
Quark Polarizations from SIDIS at JLab
J.P. Chen.. 37
Inclusive and SIDIS at COMPASS
H. Santos.. 43
Fragmentation functions and SIDIS
M. Stratmann.. 49
SIDIS and HERMES
E. Kinney.. 55
Future SIDIS studies at Jlab
X. Jiang.. 61
Plans and prospects for W-physics with PHENIX
R. Seidl.. 69
Plans and prospects for W-physics with STAR
F. Simon.. 77
W reconstruction at the Tevatron and SPS
M. Rijssenbeek.. 83
Threshold resummation for W production at RHIC
A. Mukherjee 89
Future possibilities for W physics
H. Yokoya.. 93
Flavor structure of the nucleon and W-production
J. C. Peng.. 99

Preface to the Series

The RIKEN BNL Research Center (RBRC) was established in April 1997 at Brookhaven National Laboratory. It is funded by the "Rikagaku Kenkyusho" (RIKEN, The Institute of Physical and Chemical Research) of Japan. The Center is dedicated to the study of strong interactions, including spin physics, lattice QCD, and RHIC physics through the nurturing of a new generation of young physicists.

The RBRC has both a theory and experimental component. The RBRC Theory Group and the RBRC Experimental Group consist of a total of 25-30 researchers. Positions include the following: full time RBRC Fellow, half-time RHIC Physics Fellow, and full-time, post-doctoral Research Associate. The RHIC Physics Fellows hold joint appointments with RBRC and other institutions and have tenure track positions at their respective universities or BNL. To date, RBRC has ~50 graduates of which 14 theorists and 6 experimenters have attained tenure positions at major institutions worldwide.

Beginning in 2001 a new RIKEN Spin Program (RSP) category was implemented at RBRC. These appointments are joint positions of RBRC and RIKEN and include the following positions in theory and experiment: RSP Researchers, RSP Research Associates, and Young Researchers, who are mentored by senior RBRC Scientists. A number of RIKEN Jr. Research Associates and Visiting Scientists also contribute to the physics program at the Center.

RBRC has an active workshop program on strong interaction physics with each workshop focused on a specific physics problem. Each workshop speaker is encouraged to select a few of the most important transparencies from his or her presentation, accompanied by a page of explanation. This material is collected at the end of the workshop by the organizer to form proceedings, which can therefore be available within a short time. To date there are eighty-three proceeding volumes available.

A 10 teraflops RBRC QCDOC computer funded by RIKEN, Japan, was unveiled at a dedication ceremony at BNL on May 26, 2005. This supercomputer was designed and built by individuals from Columbia University, IBM, BNL, RBRC, and the University of Edinburgh, with the U.S. D.O.E. Office of Science providing infrastructure support at BNL. Physics results were reported at the RBRC QCDOC Symposium following the dedication. QCDSP, a 0.6 teraflops parallel processor, dedicated to lattice QCD, was begun at the Center on February 19, 1998, was completed on August 28, 1998, and was decommissioned in 2006. It was awarded the Gordon Bell Prize for price performance in 1998.

N. P. Samios, Director
March 2007

Introduction

The RHIC spin program is now fully underway. Several runs have been successfully completed and are producing exciting first results. Luminosity and polarization have improved remarkably and promising advances toward the higher RHIC energy of $\sqrt{s} = 500$ GeV have been made. At this energy in particular, it will become possible to perform measurements of parity-violating spin asymmetries. Parity violation occurs in weak interactions, and in combination with the unique polarization capabilities at RHIC fascinating new opportunities arise. In particular, parity-violating single- and double-spin asymmetries give new insights into nucleon structure by allowing probes of up and down sea and anti-quark polarizations. Such measurements at RHIC are a DOE performance milestone for the year 2013 and are also supported by a very large effort from RIKEN. With transverse polarization, charged-current interactions may be sensitive to the Sivers effect. Parity-violating effects at RHIC have been proposed even as probes of physics beyond the Standard Model.

With the era of measurements of parity-violating spin asymmetries at RHIC now rapidly approaching, we had proposed a small workshop that would bring together the main experts in both theory and experiment. We are very happy that this worked out. The whole workshop contained 17 formal talks, both experiment (10) and theory (7), and many fruitful discussions. The physics motivations for the planned measurements were reviewed first. The RHIC machine prospects regarding polarized 500 GeV running were discussed, as well as the the plans by the RHIC experiments for the vital upgrades of their detectors needed for the W physics program. We also had several talks on the topic of "semi-inclusive deep-inelastic scattering", which provides different access to related physics observables. On the theory side, new calculations were presented, for example in terms of QCD all-order resummations of perturbation theory. Also, new observables, such as jet and W+charm final states and spin asymmetries in Z production, were proposed and discussed. All of the talks attracted much interest and initiated active discussions.

This was a very successful workshop. It stimulated many discussions and new collaborations. We are grateful to all participants and speakers for coming to the Center, and for their excellent work. The support provided for this workshop by Dr. N. Samios and his RIKEN-BNL Research Center has been magnificent, and we are very grateful for it. We thank Brookhaven National Laboratory and the U.S. Department of Energy for providing the facilities to hold the workshop. Finally, sincere thanks go to Jane Lysik for her efficient work on organizing and running the workshop.

BNL, June 2007

Matthias Grosse-Perdekamp, Bernd Surrow, Werner Vogelsang

Spin and W physics at RHIC-BNL

Jacques Soffer

Temple University, Department of Physics
Philadelphia, PA 19122, USA

Abstract

We will carefully reexamine the production of the Standard Electroweak Model gauge bosons, such as $W^{\pm}$ and Z, in pp collisions up to $\sqrt{s} = 0.5$ TeV, in connection with the future possibilities at RHIC-BNL, to reach this energy with a high luminosity.
We will stress the importance of measuring unpolarized cross sections and parity violating asymmetries to improve our present knowledge on unpolarized and polarized parton distribution functions. In particular, $W^{\pm}$ production is an essential tool to perform the flavor separation of the light quarks and antiquarks distributions.
We will also consider the optional possibility to have transversely polarized proton beams for the determination of the transversity quark distributions.
Finally, we will touch the interesting subject of searching for new physics, by looking at the parity violating asymmetry in single-jet production at high p_T.

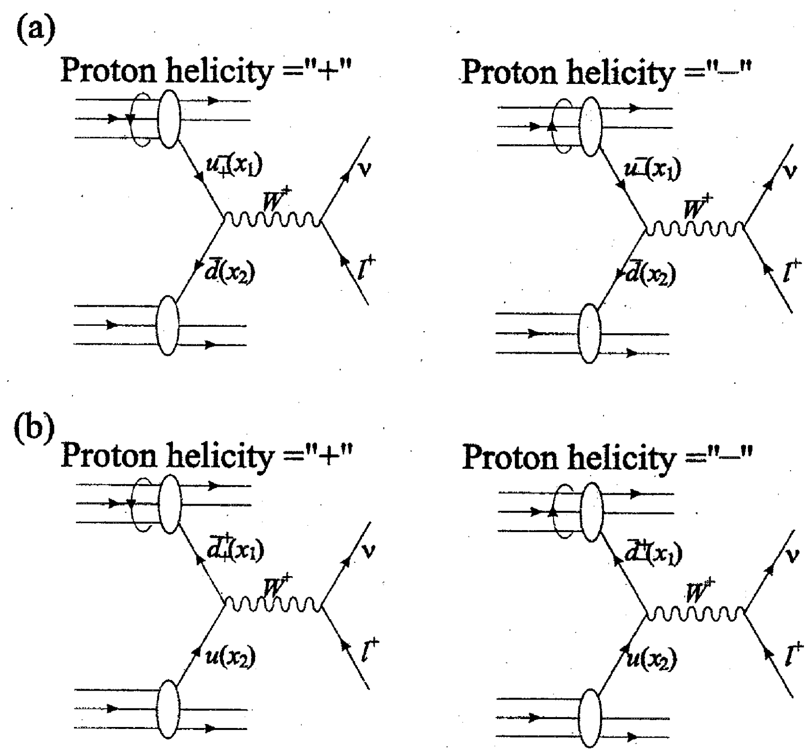
Outline

- Digression on unpolarized parton distribution functions
  - u/d from the charge asymmetry in $\bar{p}p$ collisions
  - Decisive test at pp RHIC for the light sea quarks asymmetry $\bar{d} - \bar{u}$
- Δq and $\Delta \bar{q}$ flavor separation from $W^{\pm}$ production at RHIC
  - pp collisions
  - pn collisions
- Transversity
- Search for new physics

Digression on statistical PDF (C. Bourrely, F. Buccella, J. S.)

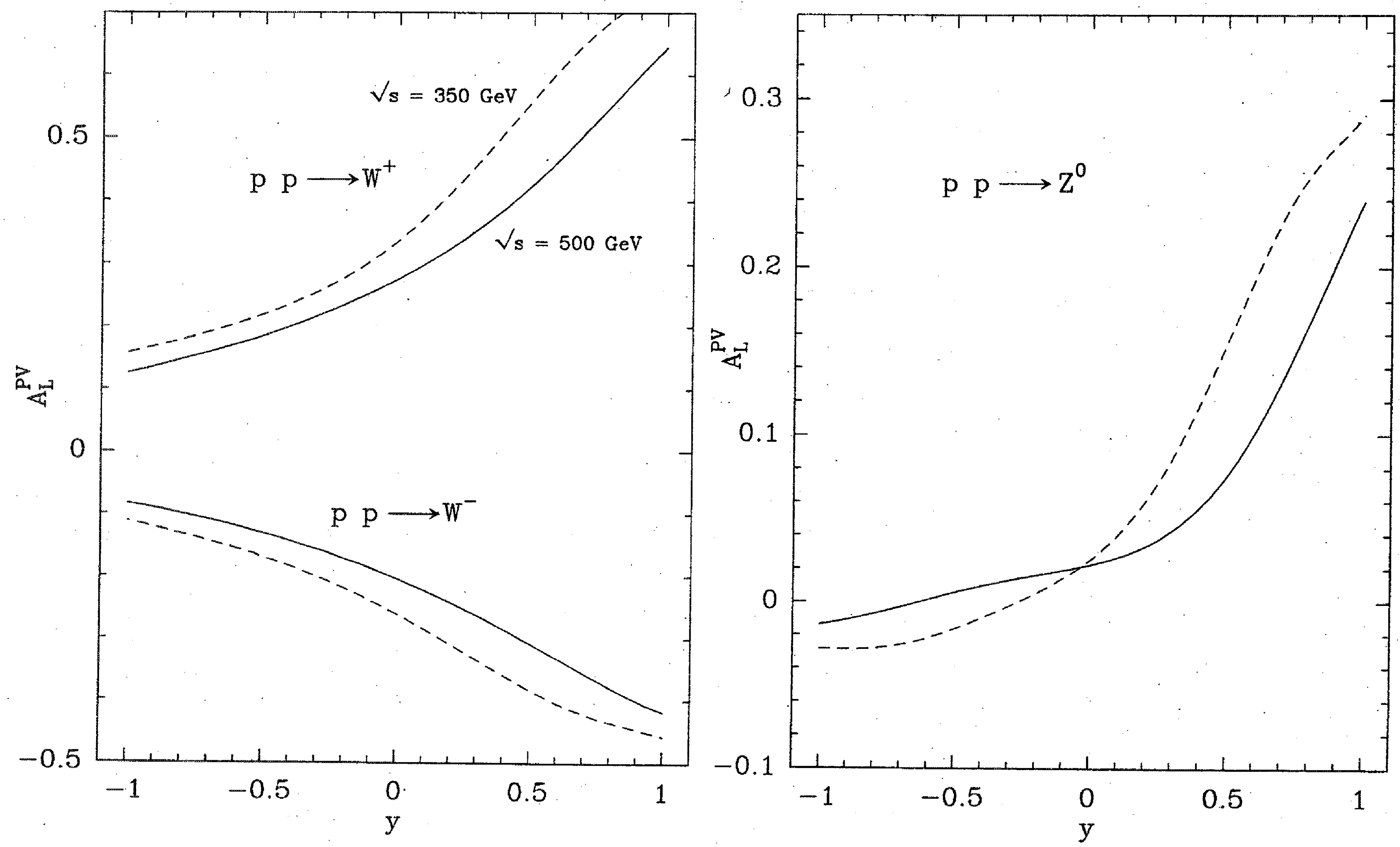
- A Statistical Approach for Polarized Parton Distributions
  Euro. Phys. J. C23, 487 (2002)
- Recent Tests for the Statistical Parton Distributions
  Mod. Phys. Letters A 18, 771 (2003)
- The Statistical Parton Distributions: status and prospects
  Euro. Phys. J. C41, 327 (2005)
- The extension to the transverse momentum dependence of the statistical parton distributions
  Mod. Phys. Letters A 21, 143 (2006)
- Strangeness asymmetry of the nucleon in the statistical parton model
  Phys. Letters B 648, 39 (2007)

W^+ production in polarized pp collisions



C. Bourrely and J. S., Phys. Lett. B314, 132 (1993)

Parity-violating asymmetries

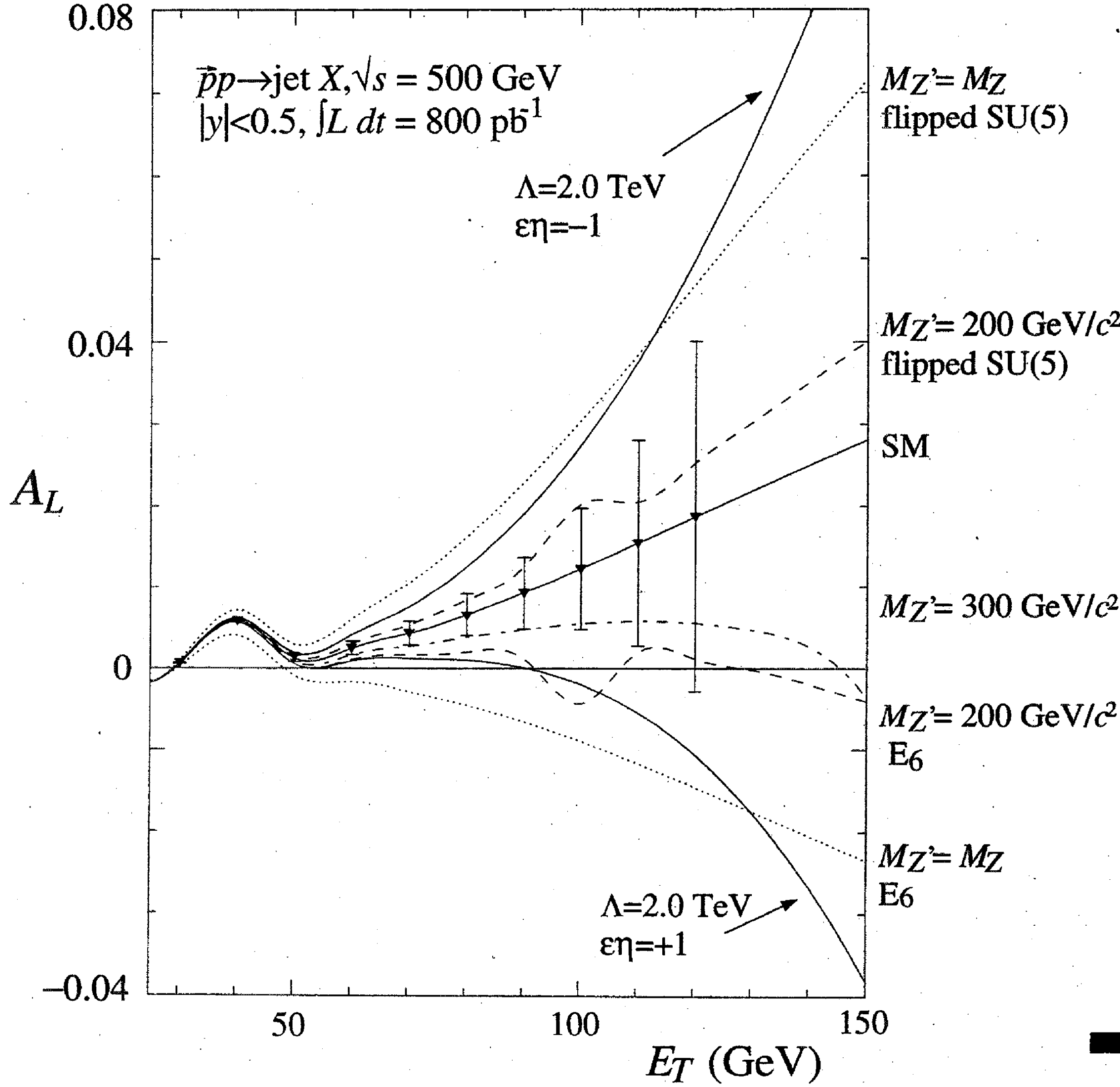


A_{TT} for Z production

$$A_{TT}(Z) = \frac{\sum_q (b_q^2 - a_q^2)\delta q(x_1, M^2)\delta\bar{q}(x_2, M^2) + (1 \leftrightarrow 2)}{\sum_q (b_q^2 + a_q^2) q(x_1, M^2)\bar{q}(x_2, M^2) + (1 \leftrightarrow 2)}$$

For W production, since W coupling is V-A i.e. $a_q = b_q$
we expect $A_{TT} = 0$ Must check this
However single spin asymmetry $A_N(W^{\pm})$ allows the flavor separation of Sivers functions for u ,$\bar{u}$, d and $\bar{d}$.
(I. Schmidt and J.S. Phys. Lett. B 563, 179 (2003))

$A_L(SM + NP)$ at RHIC (P. Taxil, J.M. Virey, PLB364,181 (1995))



Christian Weiss
Jefferson Lab – Theory Center

Models for Polarized Nucleon Sea

Sea quark polarization and nucleon structure

Ch. Weiss (JLab), PVAS Workshop, BNL, Apr. 26–27, 2007

Q: "How" do polarized sea quarks appear in nucleon?

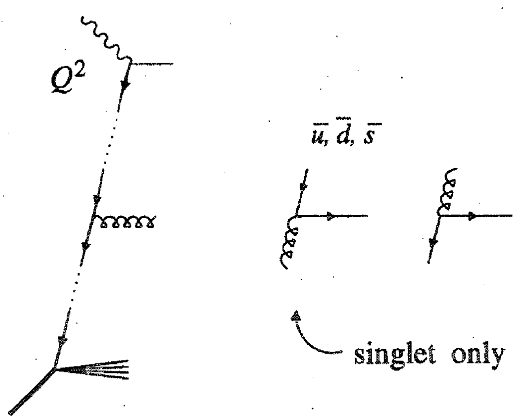
- Dynamical models of nucleon structure

  "Pion cloud," Pauli blocking

- General properties of QCD

  Chiral dynamics, large–N_c limit, . . .

PDFs in QCD: Non-singlets vs. singlet



$\bar{u} + \bar{d} + \bar{s}$	singlet
$\bar{u} - \bar{d}$	non-singlet
$\bar{u} + \bar{d} - 2\bar{s}$	non-singlet

- Non-singlet sea quark distributions do not mix with gluon
  cf. valence $q - \bar{q}$

- Total numbers conserved in LO

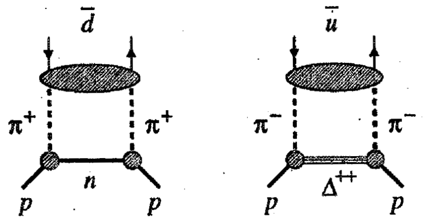
$$\int dx \left[\bar{u} - \bar{d}\right](x, Q^2) \quad = \quad \text{const}$$

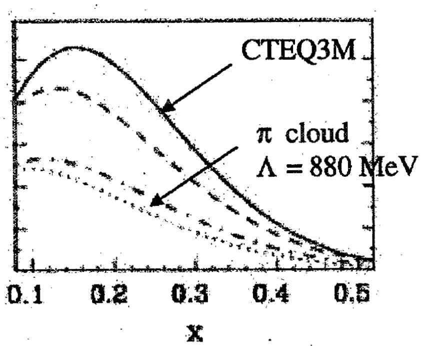
$$\Delta\bar{u} - \Delta\bar{d} \quad \text{etc.}$$

NLO: Weak Q^2–dependence

Non-perturbative origin! "Creation, not evolution"

Pion cloud: Flavor asymmetry $\bar{d} - \bar{u}$



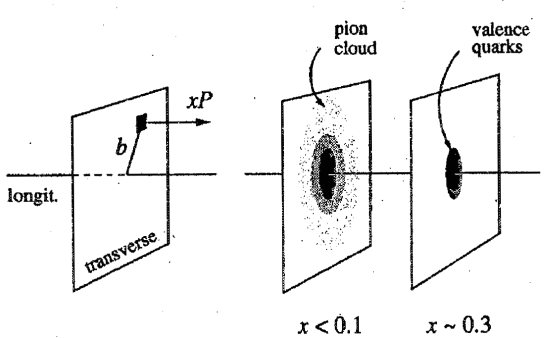


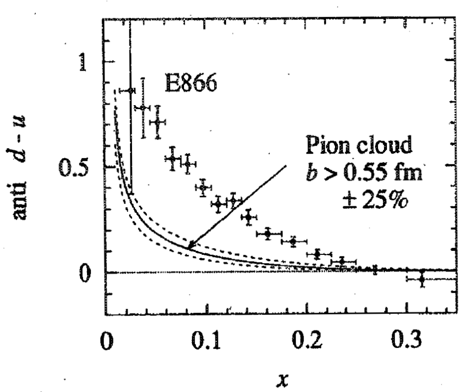
Koepf et al., PRD 53, 2586 (1996)

- Qualitatively explains why $\bar{d} > \bar{u}$ in proton [Sullivan 72, Thomas 83]
- Quantitative fit of data requires unrealistic hard πN formfactors $\Lambda > 1\,\text{GeV}$ (cf. Bonn potential) [Jülich group 90's, . . .]
- More realistic soft formfactors give at most 50% of exp. value [Koepf, Frankfurt, Strikman 95]

Consistent with chiral dynamics?

Pion cloud: Impact parameter representation



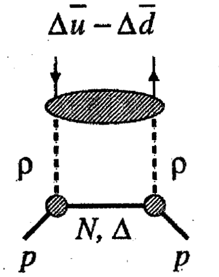


- Impact parameter–depend. PDF
$$q(x) = \int d^2b \, q(x, b)$$
- Pion cloud unique contribution at
$$b \sim 1/M_\pi \qquad \text{“Yukawa tail”}$$
$$x < M_\pi / M_N$$
- Large–b region accounts for only small part of exp. asymmetry!

Model–independent formulation, consistent with chiral dynamics

Strikman, CW 03/07

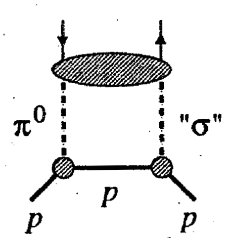
Pion cloud: Polarization



- $\pi\pi$ gives zero polarized asymmetry

- Various models with vector meson exchange give very small polarized asymmetry
  . . . not distinctive . . . arbitrary!

  [Fries et al. 98; Boreskov et al. 98, Cao et al. 01, . . .]



- π–"σ" interference with hard formfactors gives large positive $\Delta\bar{u} - \Delta\bar{d}$
  → qualitative agreement with quark models!

  [Dressler et al. 99; Fries, Schäfer, CW 02]

$\pi\sigma$ closest analog to $\pi\pi$ in polarized case . . . qualitative picture!

Large–N_c limit: Scaling of PDFs

- General N_c scaling of PDFs ($x \sim 1/N_c$) [Diakonov et al. 96]

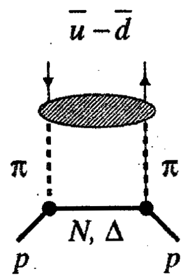
$$\bar{u} + \bar{d},\ \Delta\bar{u} - \Delta\bar{d} \ \sim\ N_c^2 \times \text{function}(N_c x) \quad \text{leading} \quad \longleftarrow$$

$$\bar{u} - \bar{d},\ \Delta\bar{u} + \Delta\bar{d} \ \sim\ N_c \times \text{function}(N_c x) \quad \text{subleading}$$

- Generally works well quantitatively
  cf. $g_A^{(3)} \sim N_c$ [num: 1.26], $g_A^{(0)} \sim N_c^0$ [num: ~ 0.3]

Large–N_c limit suggests $\lvert\Delta\bar{u} - \Delta\bar{d}\rvert \gg \lvert\bar{u} - \bar{d}\rvert$ . . . no dynamics yet!

Large–N_c limit: Pion cloud in $\bar{d} - \bar{u}$



$$g_{\pi NN} \sim N_c^{3/2}$$
$$x_\pi \sim N_c^{-1}$$

- Nucleon intermediate state alone gives
  $\bar{u} - \bar{d} \sim N_c^2 \times \text{function}(N_c x)$ ↯ subleading!

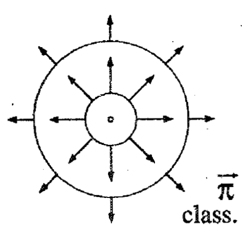
- N and Δ degenerate at large N_c:
  $$M_N - M_\Delta \sim N_c^{-1}, \quad g_{\pi N \Delta} = \frac{3}{2} g_{\pi NN}$$

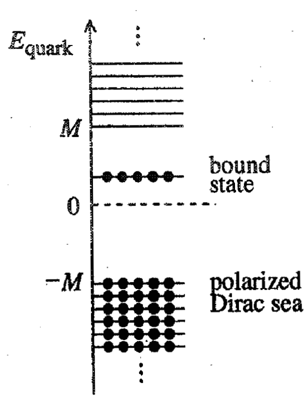
- Cancellation between N and Δ restores proper subleading behavior

Pion cloud contribution to $\bar{u} - \bar{d}$ absent in large–N_c limit!

Strikman, CW 03

Chiral quark–soliton model: Concept





- Generic model of nucleon based on
  - Large–N_c limit
  - Effective chiral dynamics

- Quarks move independently in self–consistent classical pion field ("soliton")

- Fully relativistic, field–theoretical description: Completeness of states
  - Partonic sum rules
  - Positivity $q(x), \bar{q}(x) > 0$

- Describes PDFs at scale $\mu \sim 600\,\text{MeV}$ ("cutoff" of chiral symmetry breaking)

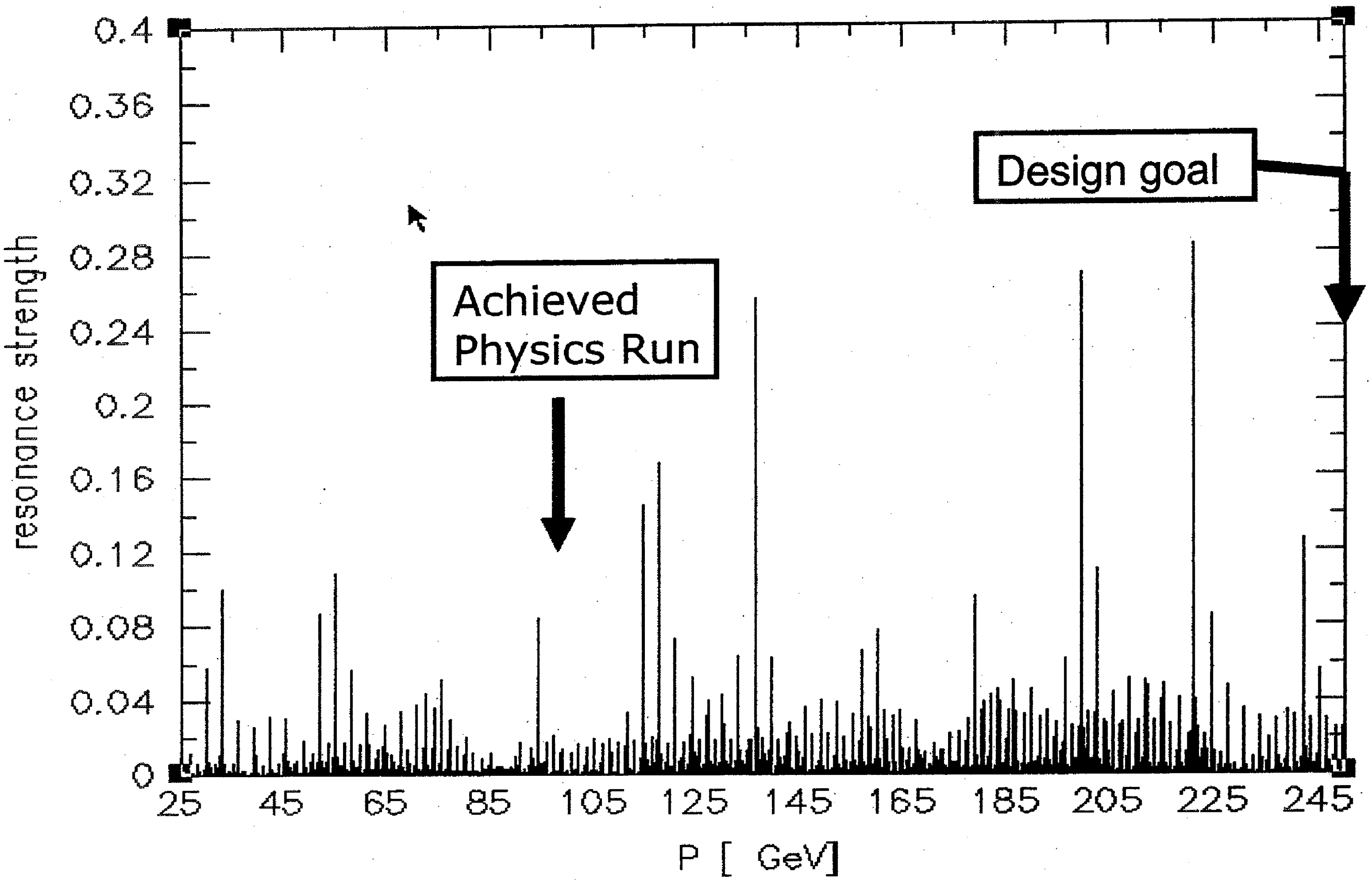
[Basics: Diakonov, Petrov, Pobylitsa 88; PDFs: Diakonov et al. 96+]

Polarized Protons in RHIC at 500 GeV

Mei Bai
C-A Dept. BNL

RHIC intrinsic spin resonance spectrum

Intrinsic spin resonance
Q_x=28.73, Q_y=29.72, emit= 10



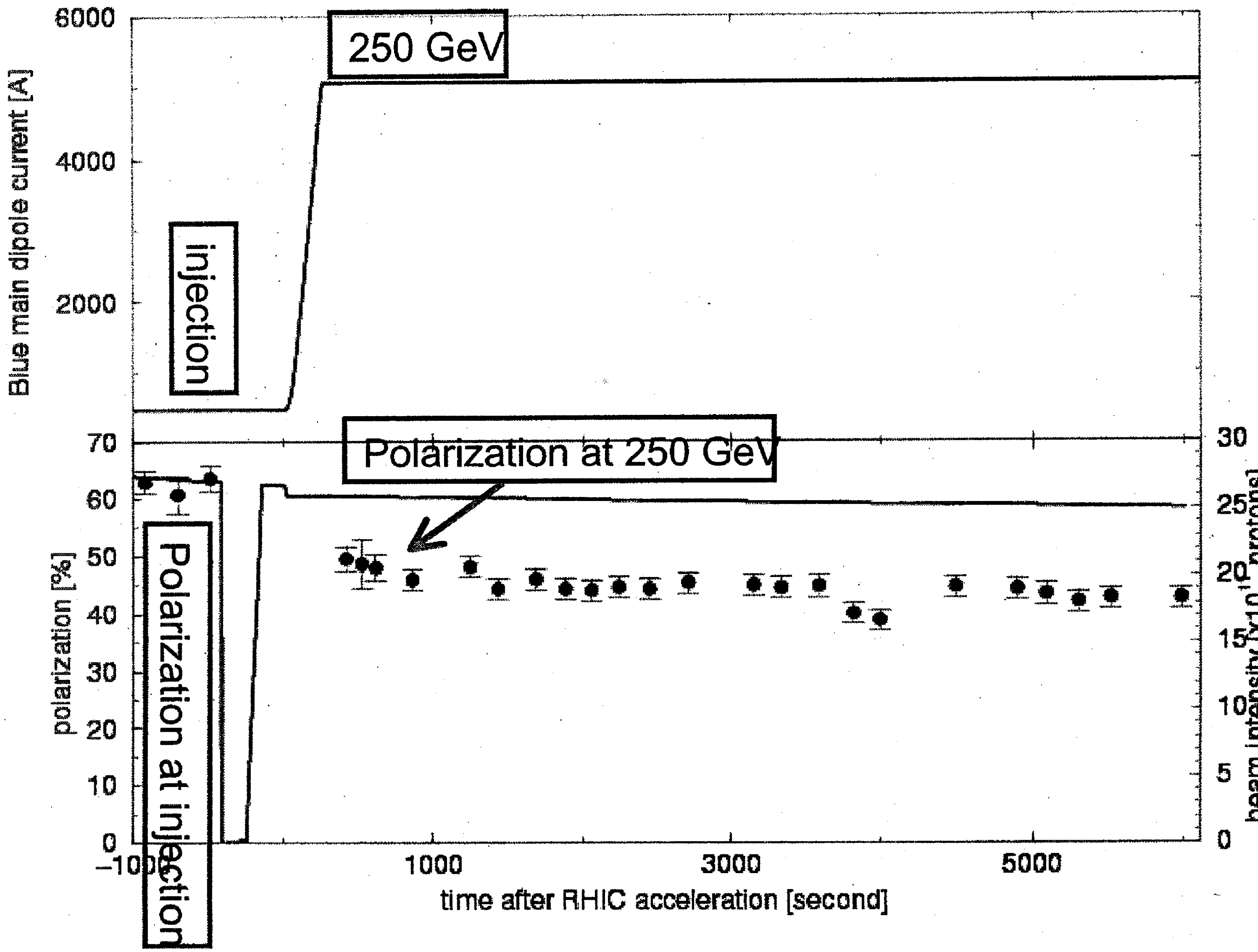
FY 2006 RHIC pp 250 GeV development(one week)

- Explore polarization transmission to a beam energy of 250 GeV
- Inspect the luminosity aspects (with 2 collisions)
  - Store lifetime
  - Total intensity limits

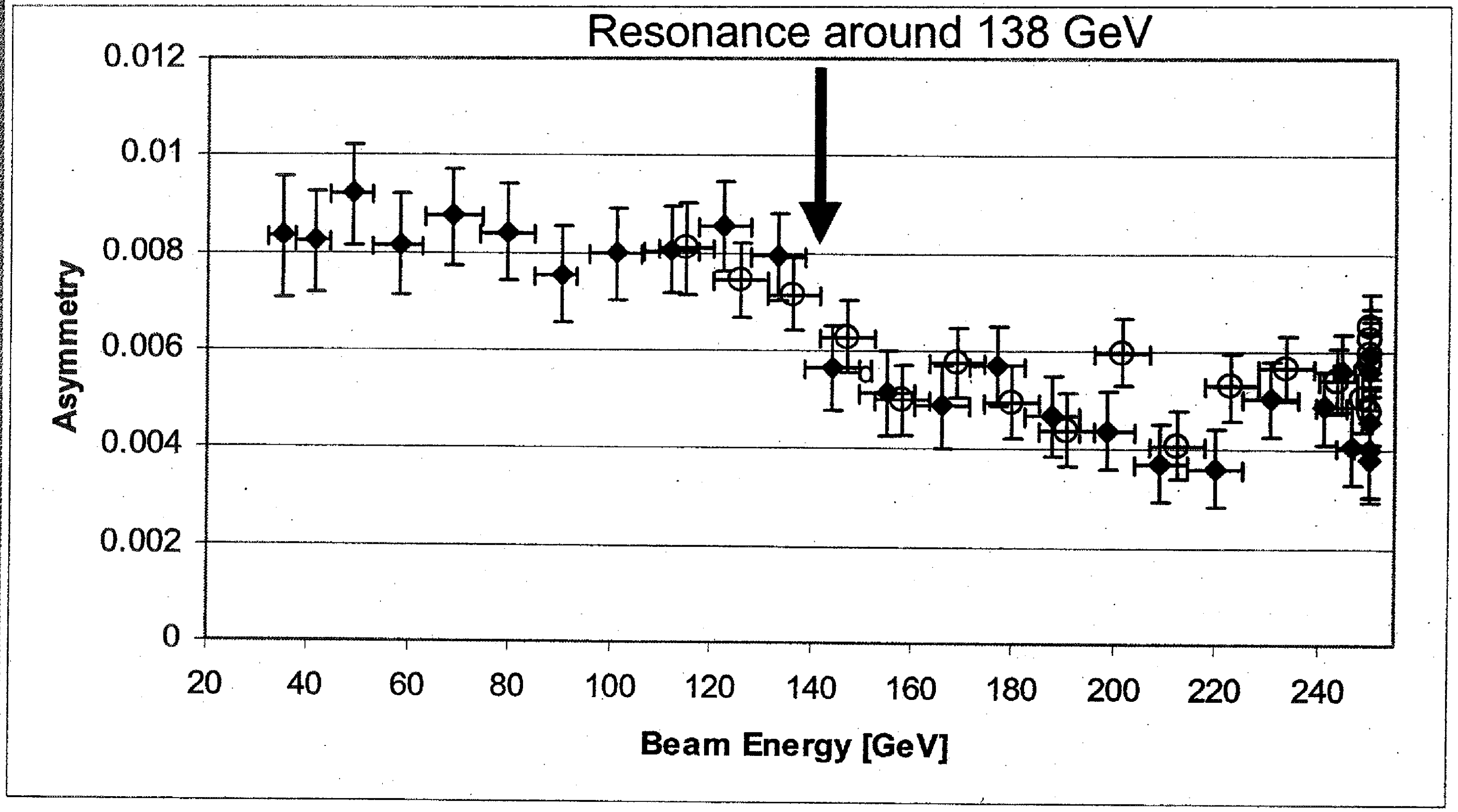
- Blue beam was first accelerated up to 250 GeV at the
  end of FY2006 pp RUN

- Polarization measurement as a function of beam energy
  identifies the location of polarization loss

pp in blue accelerated to 250 GeV with 45% polarization



RHIC pp polarization ramp measurement



Remaining issues of RHIC pp 250 GeV development

- Exam the polarization transmission efficiency in Yellow
- Systematic study of polarization along the energy ramp as function of orbit distortion and beam tunes at depolarization resonances beyond 100 GeV
- Establish collisions to study the luminosity aspects at 250 GeV
- Study the polarization lifetime as a function of beam tunes at 250 GeV

Pavel Nadolsky
Argonne National Laboratory

RHICBOS Studies

Single-spin asymmetries in W and Z boson production +RhicBos update

Pavel Nadolsky

Argonne National Laboratory

April 26, 2007

Summary

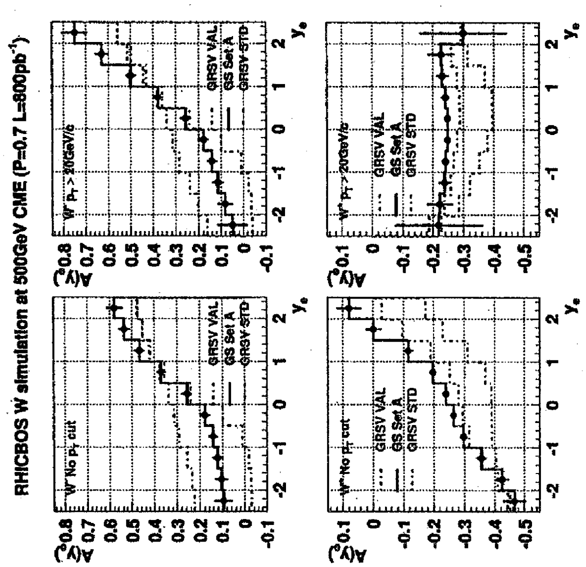
Single-spin asymmetries in W production provide exciting opportunities

- First measurements may be done in the hadronic decay mode
- Refined measurements in the lepton decay mode
- Possibilities to explore spin dependence of transverse momentum degrees of freedom in the nucleon

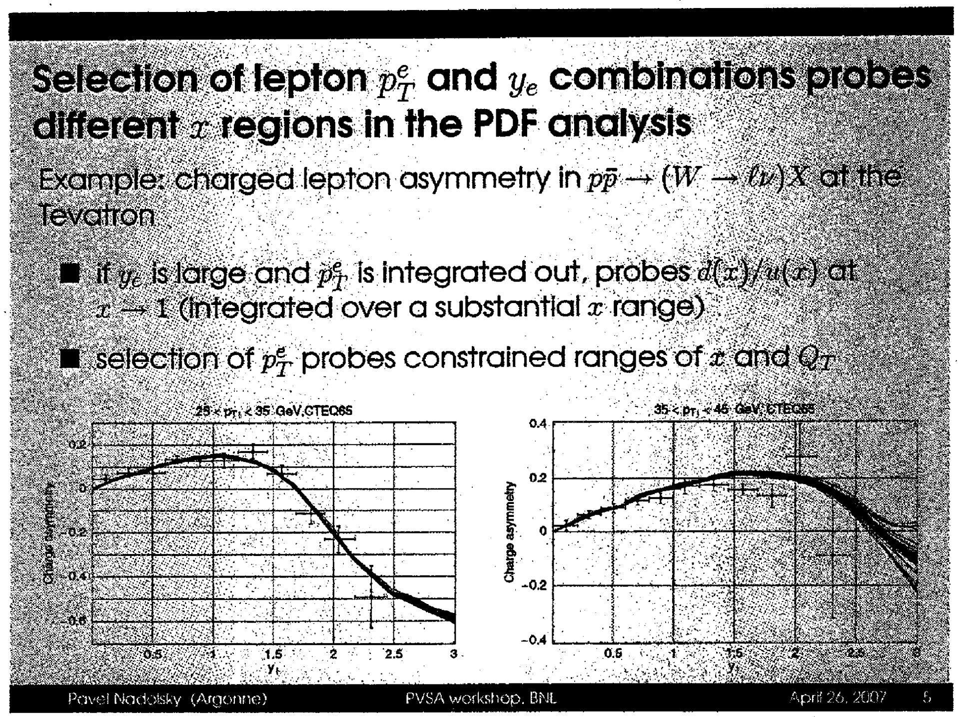
RhicBos: resummation program for polarized $W^{\pm}$, Z^{0}, and γ^{*} production

(P. N., C.-P. Yuan, Nucl. Phys. B666, 3 (2003); Nucl. Phys. B666, 35 (2003))

- Monte-Carlo integrator with resummation of soft gluons at NNLL/NLO accuracy
- effects of boson's width and decay, electroweak corrections
- unpolarized, single-spin, and double-spin cross sections
- lepton distributions for realistic acceptance
- available at MSU Q_T resummation portal (http://hep.pa.msu.edu/resum/), together with theory introduction, bibliography, etc.
- new: resummed input grids for de Florian-Sassot (2005), Bourelly-Soffer-Buccella, and other PDF's



RHICBOS W simulation at 500GeV CME (P=0.7 L=800pb^-1)
W+ No P_T cut
W+ P_T > 20GeV/c
W- No P_T cut
W- P_T > 20GeV/c
GRSV VAL
GS Set A
GRSV STD
A(y_e)
y_e


Selection of lepton p_T^e and y_e combinations probes different x regions in the PDF analysis
Example: charged lepton asymmetry in $p\bar{p} \to (W \to \ell\nu)X$ at the Tevatron
if y_e is large and p_T^e is integrated out, probes $d(x)/u(x)$ at $x \to 1$ (integrated over a substantial x range)
selection of p_T^e probes constrained ranges of x and Q_T
25 < $p_{T\ell}$ < 35 GeV,CTEQ6S
35 < $p_{T\ell}$ < 45 GeV,CTEQ6S
Charge asymmetry
y_ℓ
Pavel Nadolsky (Argonne)
PVSA workshop, BNL
April 26, 2007
5

Hadronic decays of W and Z bosons

- The $W \to e\nu$ decay is the golden mode at large luminosities ($\mathcal{L} > 300\ \mathrm{pb}^{-1}$)
- Hadronic decays may be competitive at RHIC for lower $\mathcal{L} \approx 100\ \mathrm{pb}^{-1}$ and reduced instrumentation (no lepton charge ID)
- Hadronic decay mode should be more accessible at RHIC than at the Tevatron or LHC
  - much lower background, especially for parity-violating A_L
  - lower resolution sufficient (not an electroweak precision measurement as at the Tevatron)

Hadronic decays: RHIC vs. SPS and Tevatron

☺ smaller $\sqrt{s}$ (500 vs. 630 and 1800 GeV):
gluon background ↓

☹ pp vs. $p\bar{p}$: gluon background ↑

⇒ background/signal≈20 for σ_L;

≈ 0 for $\Delta_L^{PV}\sigma$ (false asymmetry only!)

☺ the background can be extrapolated from the sidebands

Hadronic vs. leptonic decays

☺ Larger cross sections: Br($W \to q_i\bar{q}_j$)/Br($W \to e\nu$) ≈ 6

☺ Direct measurement of $d\sigma/dy_W$ possible

☹ Energy & mass resolution≈ 10 GeV; no charge ID
W^+, W^- and Z^0 cannot be separated

☹ Increased Z^0 contamination: Br(Z→ $q\bar{q}$)/Br($Z \to e^+e^-$) ≈ 20

In resonant (s-channel) production:

leptonic decays: $\sigma_{W^+} : \sigma_{W^-} : \sigma_{Z^0} = 1 : 0.33 : 0.08$

hadronic decays: $\sigma_{W^+} : \sigma_{W^-} : \sigma_{Z^0} = 1 : 0.33 : 0.26$

☹ t, u channel contributions in Z production (S. Arnold's talk)

☺ The Z^0 component can be reduced by reweighting M_{jj} bins

Simone Arnold
Ruhr-Universitaet Bochum

Longitudinal single-spin asymmetries in pp scattering with a hadronic final state

RUHR-UNIVERSITÄT BOCHUM
Institut für Theoretische Physik II

Longitudinal single-spin asymmetries in $p^{\uparrow}p$ - scattering with a hadronic final state

In this talk predictions for the single-spin asymmetry A_L with hadronic final states are presented. The asymmetry has been calculated for jets as well as for a charmed final state. Furthermore different inputs for the helicity distribution Δq have been used to see how A_L varies. Also resummed cross-sections to leading-logarithm are presented.

Simone Arnold
In collaboration with A.Metz, P.Schweitzer, W.Vogelsang

Institut für Theoretische Physik II
Ruhr-Universität Bochum – 44780 Bochum

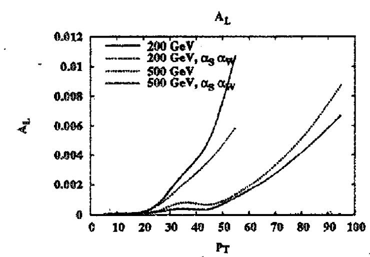
BNL, Workshop on Parity-Violating Asymmetries, 04-26-2007

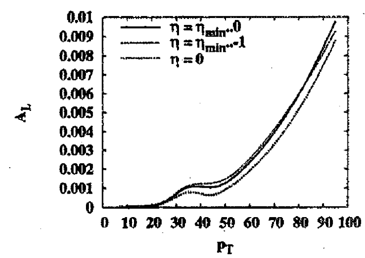
supported by BMBF

Simone Arnold *Longitudinal single-spin asymmetries in $p^{\uparrow}p$ - scattering with hadronic final state*

RUHR-UNIVERSITÄT BOCHUM
Institut für Theoretische Physik II

maximized Asymmetry





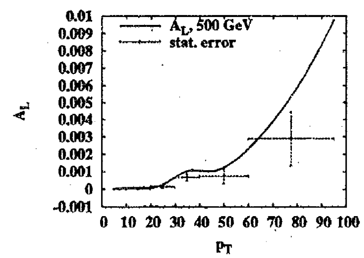
Left: A_L for different center-of-mass energies ($\sqrt{s} = 200$ GeV and 500 GeV) at $\eta = 0$ taking into account contributions up to $\mathcal{O}(\alpha_S \alpha_W)$ and $\mathcal{O}(\alpha_W^2)$.
Right: A_L as a function of transverse jet momentum, integrated over different η-ranges

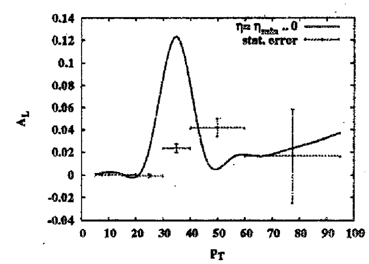
supported by BMBF

c-quark in final state

- suppress large gluon contributions in denominator of asymmetry
- no charm contribution in initial state
- look for c-quark in final state $\longrightarrow$ detect D-Meson
- $P_{c\to D} \gg P_{q\to D}$, $P_{c\to D} \gg P_{c\to \bar{D}}$ $\longrightarrow$ c-quark can be identified directly
- reduces the number of processes which contribute to the asymmetry
- determine important η-region in the same way as before.
- $\Rightarrow$ main contributions are $\mathcal{O}\left(\alpha_W^2\right)$
- $\longrightarrow$ increase of asymmetry!

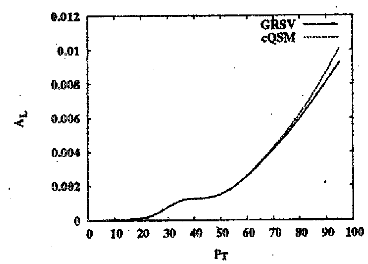
statistical error

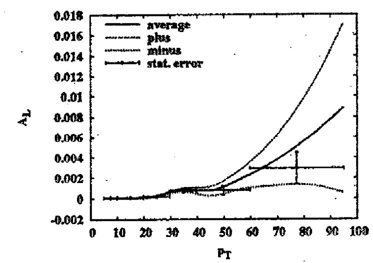




A_L with estimated statistical error. The error in p_T direction indicate the p_T bins which have been used to calculate the errors.

A_L with varying $\Delta q(x)$



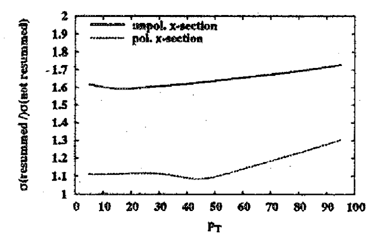


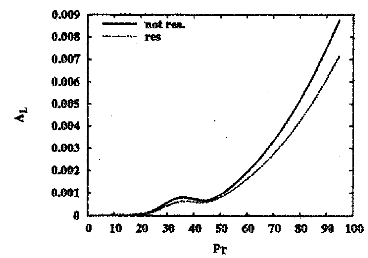
Left: Δq from chiral Quark Soliton Model
Right: A_L varying with the uncertainty in Δq

D.Diakonov, V.Petrov, P.Pobylitsa, M.Polyakov and C.Weiss
Nucl. Phys. B **480**, 341 (1996)

J. Bluemlein and H. Boettcher ; Nucl.Phys.**B**636 (2002) 225

Leading-Log resummation





Left: ratio of resummed cross-sections to unresummed cross-section. Both cross-sections become larger, the unpolarized cross-section is enhanced more, because the resummation mostly effect the gluon contributions which are missing in the polarized case. Right: resummed A_L as a function of p_T, $\eta = \eta_{min} = 0$, $\sqrt{s} = 500$ GeV compared to the unresummed A_L

supported by BMBF

Spin-Flavor Decomposition

J. P. Chen, Jefferson Lab

PVSA Workshop, April 26-27, 2007, Brookhaven National Lab

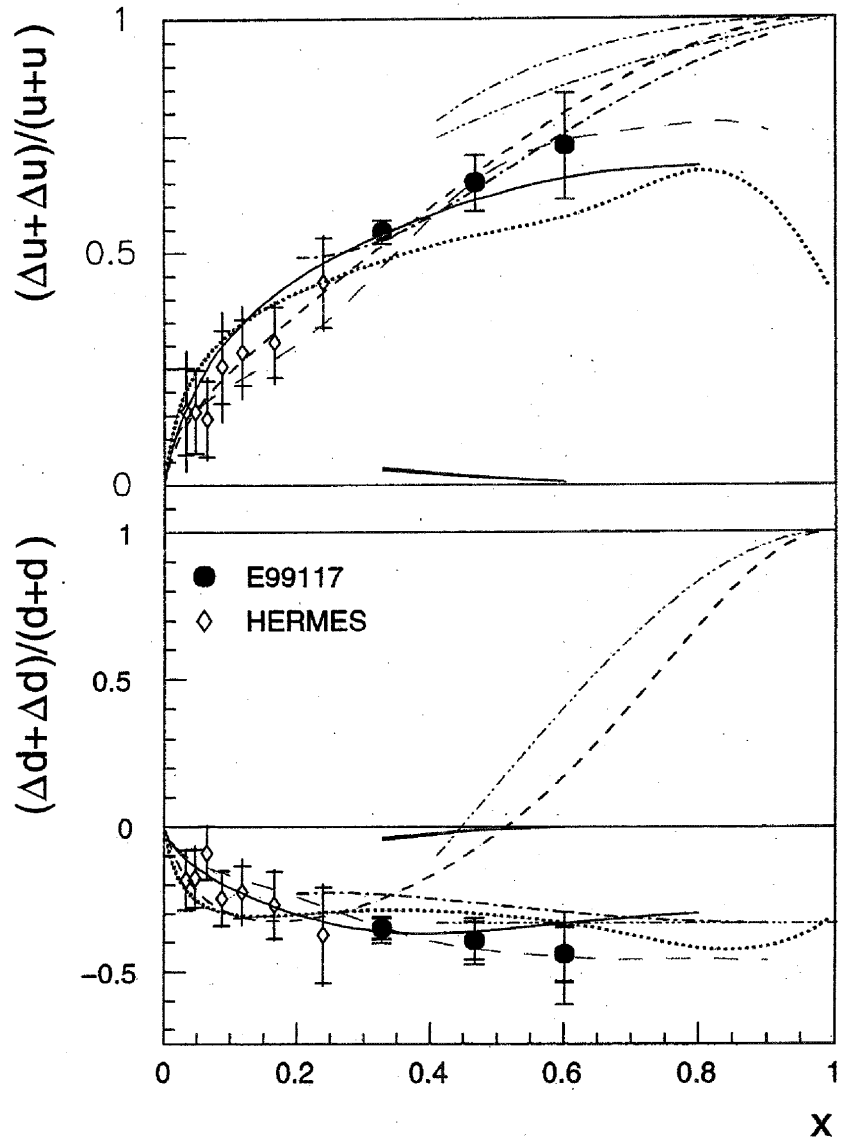
- Polarized Inclusive DIS, $\Delta u/u$ and $\Delta d/d$ from A_1^n/A_1^p
  - ➢ Spin-Flavor decomposition in high-x (valence) region
- Polarized Semi-Incluisve DIS
  - ➢ Spin-Flavor decomposition in moderate-x region
- Polarized Parity-Violating DIS
  - ➢ A new window to study sea quark polarization

❑ JLab 12 GeV upgrade and a large acceptance solenoid detector

- ➢ A powerful tool for nucleon spin-flavor decomposition

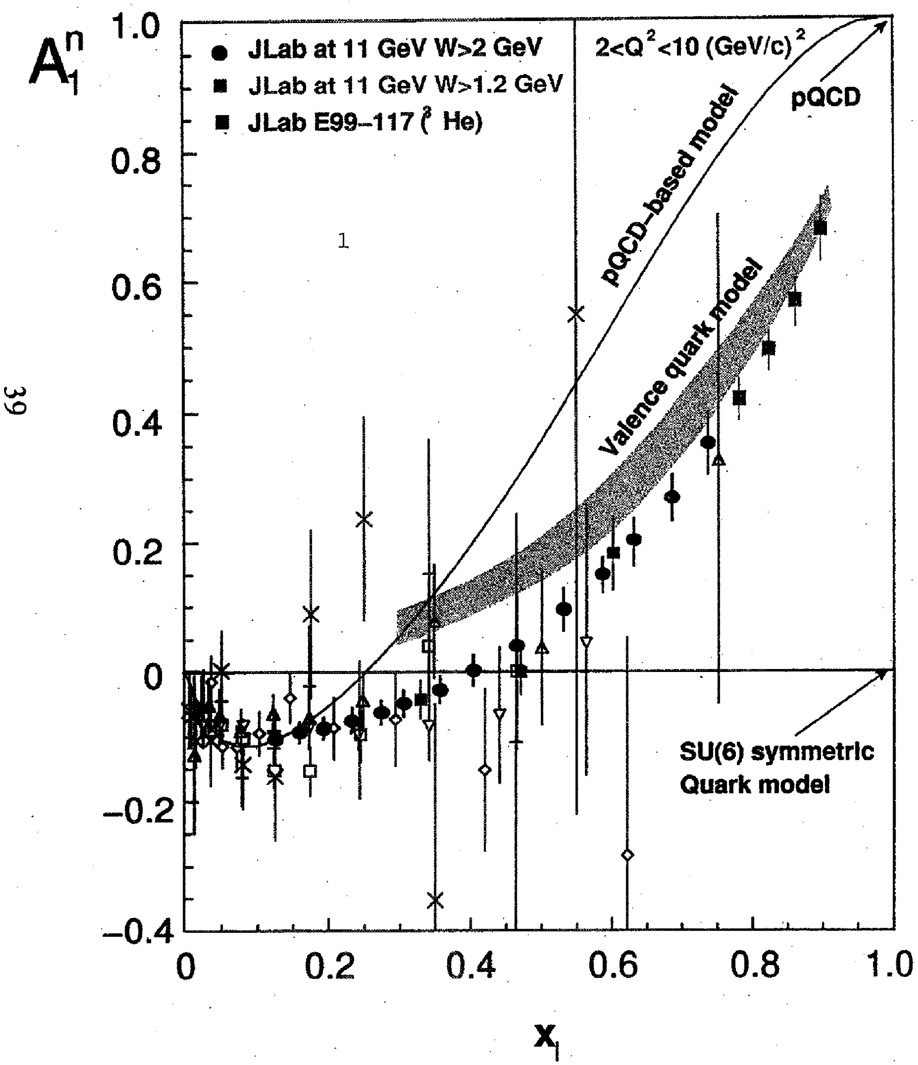
Polarized Quark Distributions at High-x with Inclusive DIS Results from JLab

- Combining A_1^n and A_1^p results
- Valence quark dominating at high x
- u quark spin as expected
- d quark spin stays negative!
  - Disagree with pQCD model calculations assuming HHC (hadron helicity conservation)
  - Quark orbital angular momentum
- Consistent with valence quark models, pQCD PDF fits without HHC constraint, statistic model
- Consistent with a new model from Feng Yuan *et al.* including OAM

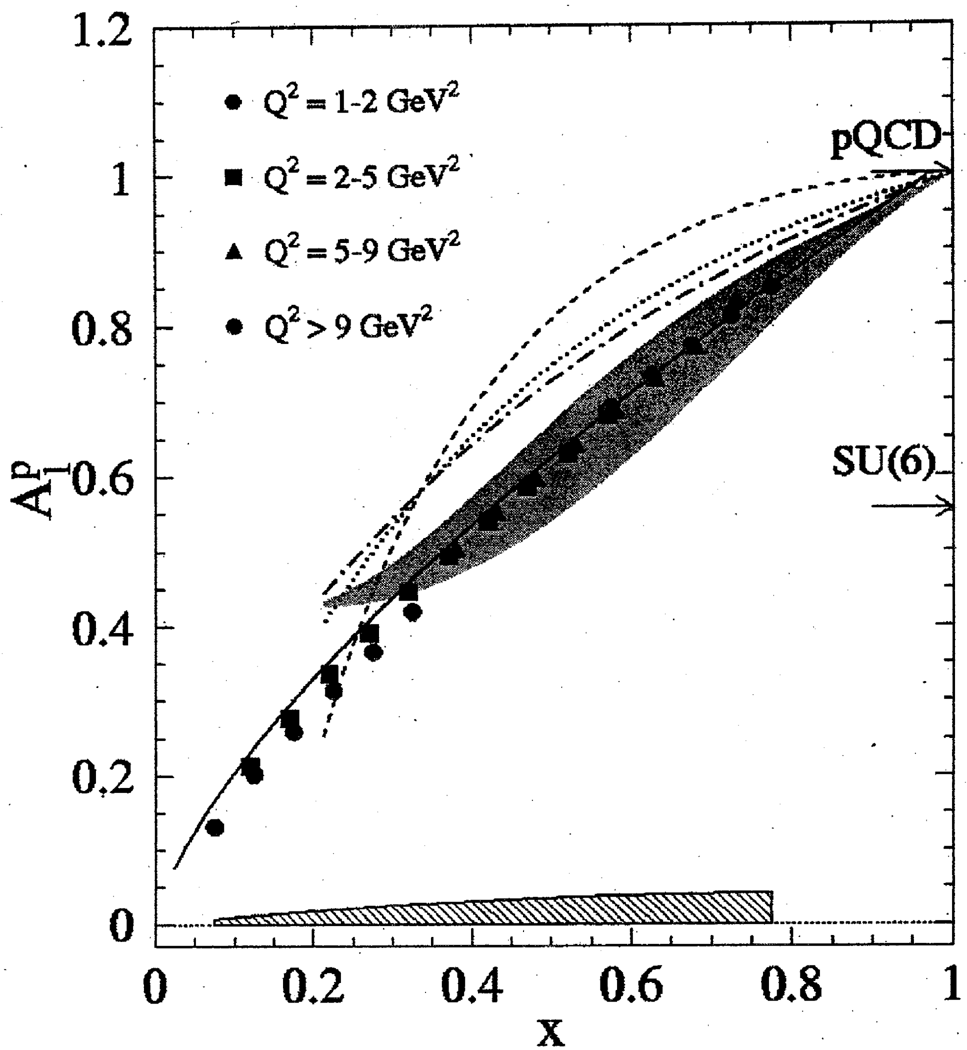


Projections for JLab at 11 GeV

A_1^n at 11 GeV

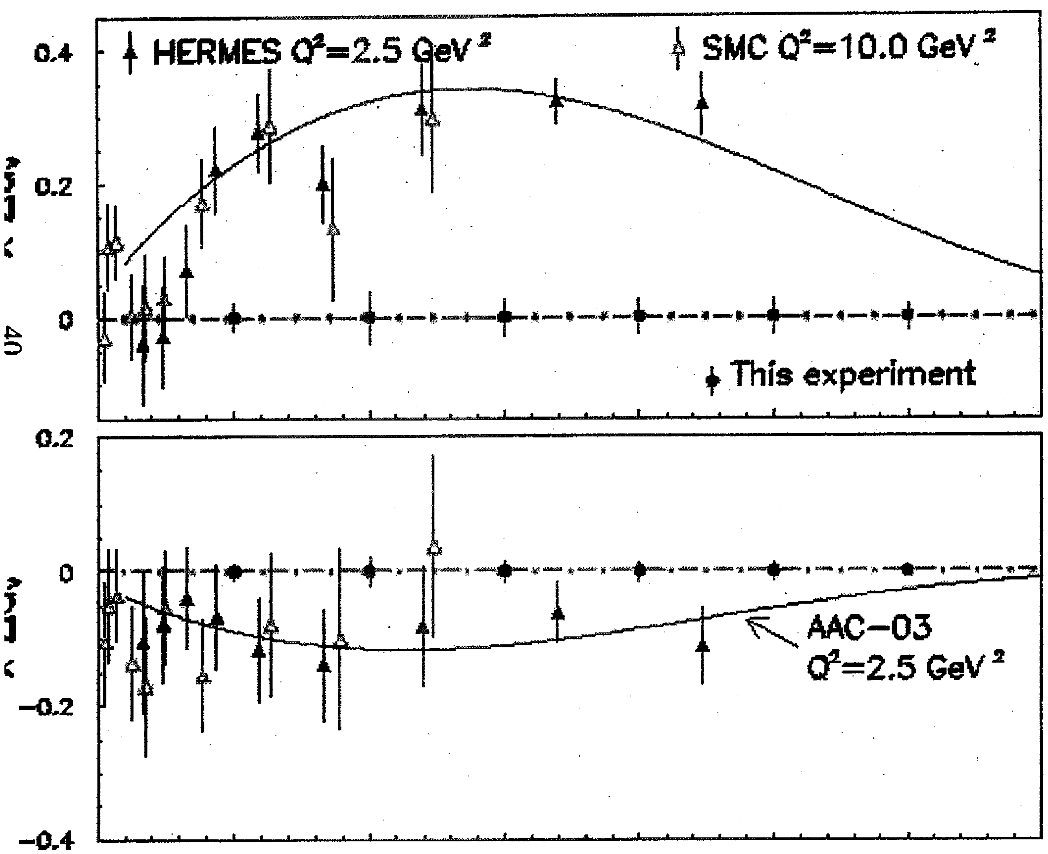


A_1^p at 11 GeV

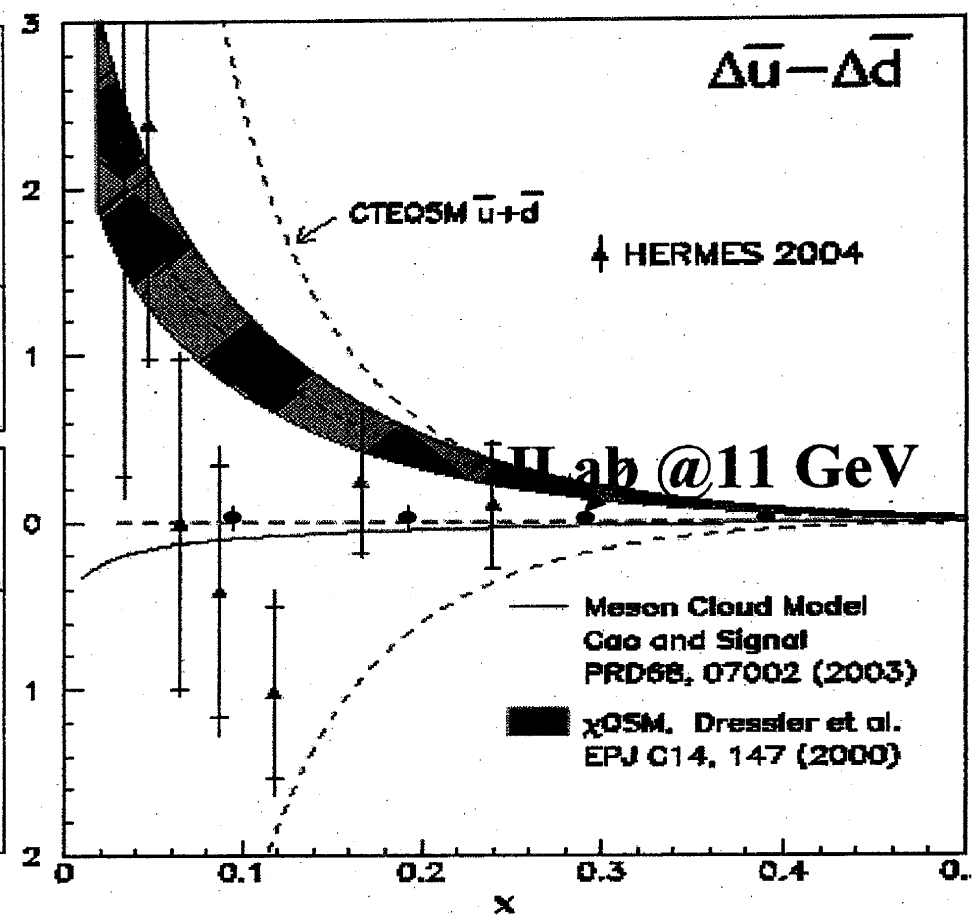


Flavor decomposition with SIDIS

Δu_v and Δd_v at JLab 11 GeV



Polarized Sea



Parity Violating Spin Structure Functions

Unpolarized beam on longitudinally polarized target

keep γZ interference terms, neglect Z^2 terms

$$\frac{d^2\sigma^{\Rightarrow}}{dxdy} - \frac{d\sigma^{\Leftarrow}}{dxdy} \approx 16\pi ME \frac{\alpha^2}{Q^4} \eta^{\gamma Z}$$

$$\{g_V[(1-y)(g_3^{\gamma Z} - g_4^{\gamma Z}) + xy^2 g_5^{\gamma Z}] + g_A xy(2-y) g_1^{\gamma Z}\}$$

in parton model

$$\frac{d^2\sigma^{\Rightarrow}}{dxdy} - \frac{d\sigma^{\Leftarrow}}{dxdy} \propto g_V (1 - y + \frac{1}{2} y^2) g_3^{\gamma Z} + g_A xy(2-y) g_1^{\gamma Z}$$

where $g_3^{\gamma Z} = 2x g_5^{\gamma Z} = 2x \sum_q e_q (g_A)_q (\Delta q - \Delta \bar{q})$

provide an access to sea polarization

Measure Parity Violating Single Spin Asymmetry at 12 GeV JLab with a Large Acceptance Solenoid Detector

- At x=0.2, Q^2=2.4, y=0.58, $A \sim 10^{-5}$-10^{-4}
- Need high luminosity and large acceptance
- Rate estimation with the Solenoid detector:

→ 1000 hours beam, statistical precision for asymmetry will be a few x 10^{-5}.

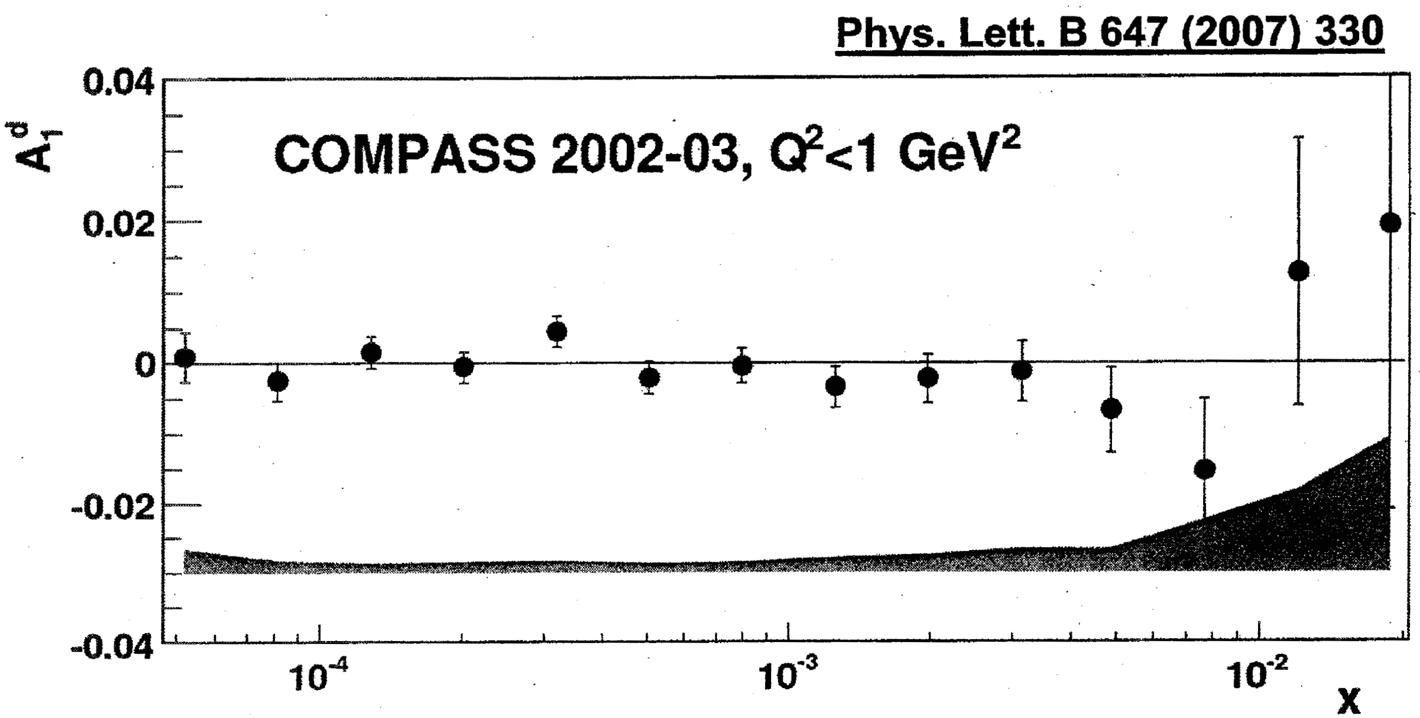
A significant first measurement (~ a few σ?)

Inclusive and SIDIS at COMPASS

Helena Santos, on Behalf of the COMPASS Collaboration
LIP - Lisbon (Laboratório de Instrumentação e Física Experimental de Partículas)

The COMPASS experiment at the CERN SPS has an extensive experimental program focused on the nucleon structure and on hadron spectroscopy. A main topic of investigation is the spin structure of the nucleon via deep-inelastic scattering of 160 GeV polarised muons on a polarised ^{6}LiD target. Results obtained in the kinematic ranges $Q^2 < 1$ $(GeV/c)^2$ and $0.0005 < x < 0.02$, as well as $1 < Q^2 < 100$ GeV^2 and $0.004 < x < 0.7$ are shown. The results of a global QCD fit at NLO to the world g_1 data are discussed.
Then, a first evaluation of the polarised valence quark distributions $\Delta u_v(x) + \Delta d_v(x)$ is presented. The analysis is based on the difference asymmetry, $A^{(h+-h-)}$, for hadrons of opposite charges. This approach gives direct access to the valence quark helicity distributions, as the fragmentation functions do cancel out in LO QCD. The results derived provide information about the contribution of the sea quarks to the nucleon spin. Comparisons with previous measurements performed at SMC and HERMES are also shown.

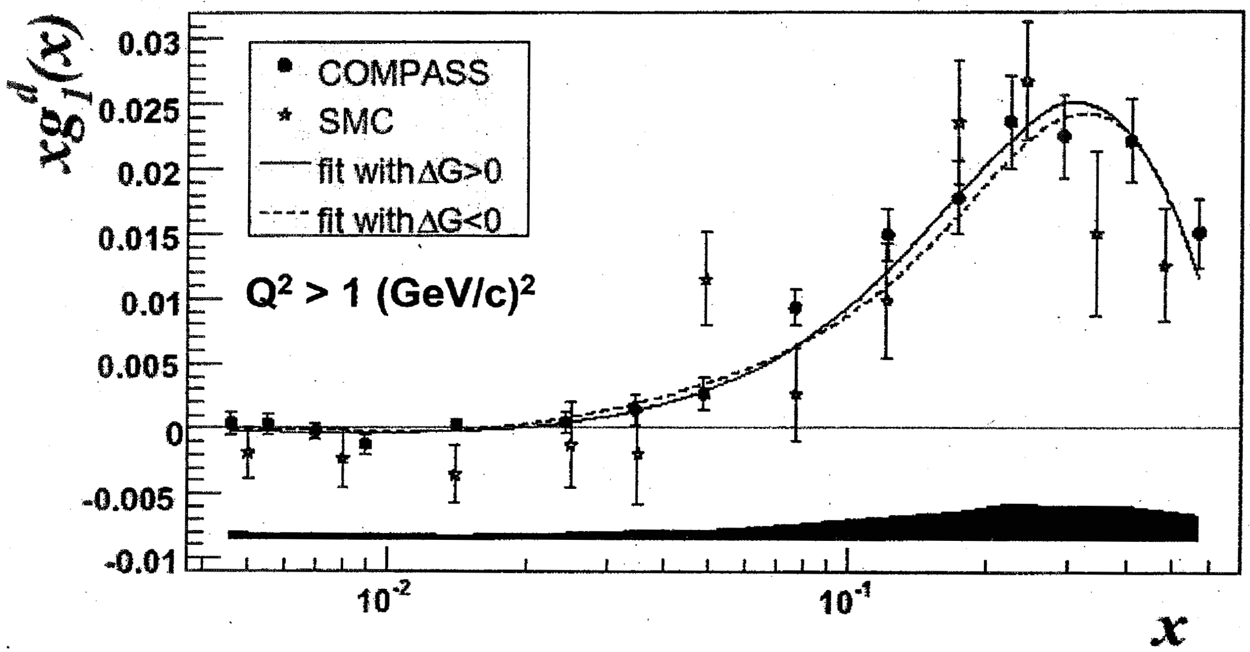
Inclusive Asymmetry, $Q^2 < 1\ (GeV/c)^2$



- A_1^d asymmetry compatible with 0 at low x range (0.0005<x<0.02)
- At low x A_1^d has been measured only by COMPASS and SMC
- Systematic errors are mainly due to false asymmetries

QCD Fits

- **Two different approaches have been used:**
  - **1 - Numerical integration in (x,Q^2) space (PRD58(1998) 112002)**
  - **2 - Solution of DGLAP in space of moments (PRD70(2004) 074032)**
- **Fits to world data → 230 world data points, 43 from COMPASS**
- **NLO analysis ($\overline{\text{MS}}$ scheme)**



Data well described by two solutions: $\Delta G > 0$ and $\Delta G < 0$

H. Santos (helena@lip.pt)

First Moment of g_1

(COMPASS data only) **Phys. Lett. B 647 (2007) 8**

$$\Gamma_1^N(Q_0^2 = 3(\mathrm{GeV}/c)^2) = \int_0^1 g_1^N(x)\,dx = 0.0502 \pm 0.0028(\mathrm{stat}) \pm 0.0020(\mathrm{evol}) \pm 0.0051(\mathrm{syst})$$

- **in literature (S.A. Larin *et al.*, PLB404 (1997) 153):**

$$\Gamma_1^N(Q^2) = \frac{1}{9}\left(1 - \frac{\alpha_s(Q^2)}{\pi} + O(\alpha_s^2)\right)\left(a_0(Q^2) + \frac{1}{4}a_8\right)$$

(from Y. Goto *et al.*, PRD62 (2000) 034017: $a_8 = 0.585 \pm 0.025$)

$$a_0(Q_0^2 = 3(\mathrm{GeV}/c)^2) = 0.35 \pm 0.03(\mathrm{stat}) \pm 0.05(\mathrm{syst})$$

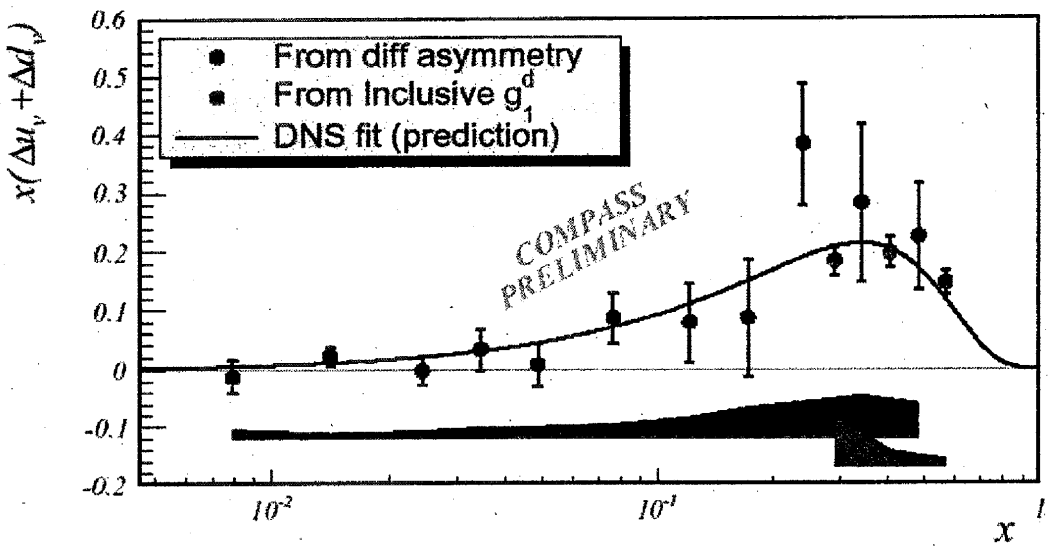
extrapolating to $Q^2 \to \infty$ $$\hat{a}_{0(Q^2\to\infty)} = 0.33 \pm 0.03(\mathrm{stat}) \pm 0.05(\mathrm{syst})$$

$\hat{a}_0$ is interpreted as the fraction of the nucleon spin carried by the quarks,
$\Delta\Sigma = \Delta u + \Delta d + \Delta s$

$$(\Delta s + \Delta\bar{s})_{(Q^2\to\infty)} = \frac{1}{3}(\hat{a}_0 - a_8) = -0.08 \pm 0.01(\mathrm{stat}) \pm 0.02(\mathrm{syst})$$

Valence quark polarisations

$$x(\Delta u_v + \Delta d_v) = \frac{x(u_v + d_v)}{(1 + R(x,Q^2))(1 - 1.5\omega_D)} A^{+-} \qquad (\omega_D = 0.05 \pm 0.01)$$



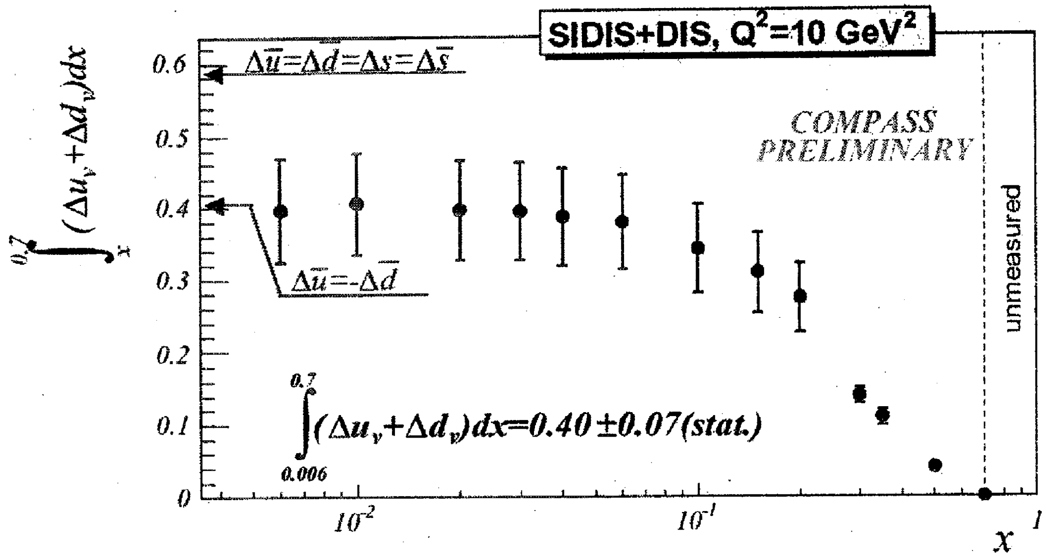
- Unpol. sea contribution to F_2 vanishes for x > 0.3
- $|\Delta\bar{u}+\Delta\bar{d}| < \bar{u}+\bar{d}$

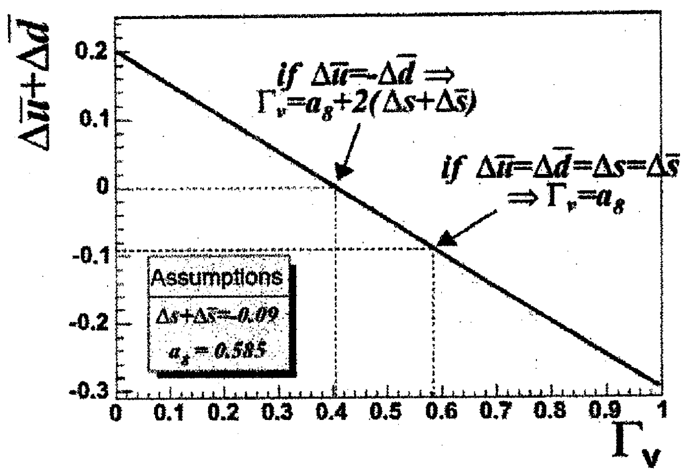
$$\boxed{\Delta u_v + \Delta d_v = \frac{36}{5}\frac{g_1^d(x,Q^2)}{(1-1.5\omega_D)}} - \left[2(\Delta\bar{u}+\Delta\bar{d}) + \frac{2}{5}(\Delta s + \Delta\bar{s})\right]$$

- Much better precision

- All points evolve to $Q_0^2 = 10\ (\mathrm{GeV}/c)^2$ accordingly to DNS parameterisation
  (D. De Florian, G.A. Navarro and R. Sassot, Phys. Rev. D71 (2005) 094018)
- LO DNS analysis, based on KKP param. of FF, includes:
  All DIS g_1 prior to COMPASS 2004 data;
  All SIDIS data from SMC and HERMES ($\Delta\bar{u} = \Delta\bar{d} = \Delta s = 0$ for x > 0.3)
- Unpolarised MRST 2004 LO PDFs have been used

Estimate for the first moments (LO)





	x-range	Q^2 GeV^2	$\Delta u_v + \Delta d_v$ measurem.	$\Delta u_v + \Delta d_v$ DNS	$\Delta\bar{u} + \Delta\bar{d}$ measurem.	$\Delta\bar{u} + \Delta\bar{d}$ DNS
SMC 98	0.003–0.7	10	$0.26 \pm 0.21 \pm 0.11$	0.386	$0.02 \pm 0.08 \pm 0.06$	−0.009
HERMES 05	0.023–0.6	2.5	$0.43 \pm 0.07 \pm 0.06$	0.363	$-0.06 \pm 0.04 \pm 0.03$	−0.005
COMPASS	0.006–0.7	10	$0.40 \pm 0.07 \pm 0.05$	0.385	$0.0 \pm 0.04 \pm 0.03$	−0.007

- **Contribution from the unmeasured 0.7 < x < 1 region is 0.004 (DNS fit)**
- **SU(3) symmetric sea was assumed in SMC**
- **The estimated Γ_v (SIDIS + DIS) is $2.5\sigma_{stat}$ away from the symmetric sea scenario**

Global Analysis of Fragmentation Functions for Pions and Kaons and Their Uncertainties

Marco Stratmann

Radiation Laboratory, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

We present [1] new sets of pion and kaon fragmentation functions obtained in NLO combined analyses of single-inclusive hadron production in electron-positron annihilation, proton-proton collisions, and deep-inelastic lepton-proton scattering with either pions or kaons identified in the final state. At variance with all previous fits, the present analyses take into account data where hadrons of different electrical charge are identified, which allow to discriminate quark from anti-quark fragmentation functions without the need of non trivial flavor symmetry assumptions. The resulting sets are in good agreement with all data analyzed, which cover a much wider kinematical range than in previous fits. An extensive use of the Lagrange multiplier technique is made in order to assess the uncertainties in the extraction of the fragmentation functions and the synergy from the complementary data sets in our global analysis.

References:

[1] D. de Florian, R. Sassot, and M. Stratmann, hep-ph/0703242 (Physical Review D).

■ global QCD analysis

plenty of data from ep and pp - so, why has it not been done already?

- NLO expressions for ep and, in particular, for pp are very lengthy & difficult to handle in fits (CPU time)
- many sources of uncertainties: experimental (syst., stat., normalization) & theory (scale variation, bias from chosen ansatz, framework, ...)

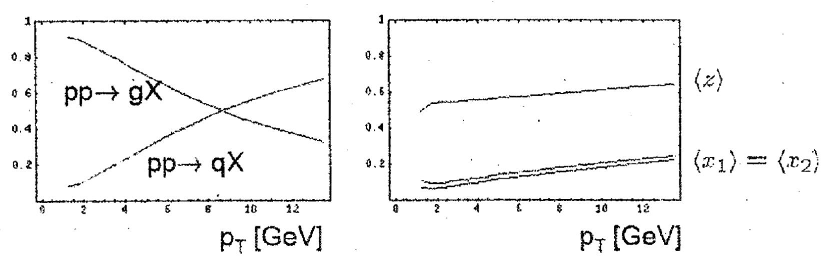
analysis collaboration formed: D. de Florian, R. Sassot (Buenos Aires) MS (RIKEN)

uses technology spin-offs & experience from global pdf analyses:

- "Mellin technique" to handle exact NLO expressions in fits
- "Lagrange multiplier" technique to estimate uncertainties
- fast & well-tested DGLAP evolution codes
- vast array of NLO calculations for ep and pp at hand

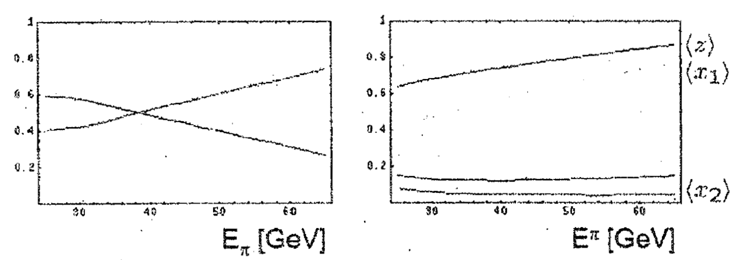
■ pp → hX data: why important?

central rapidity (PHENIX data)



→ low p_T data probe gluon fragmentation

forward rapidity (STAR data)



→ probe gluon and quark fragmentation at large z

BRAHMS $\pi^\pm$, $K^\pm$ data ($\eta \simeq 3$) → flavor separation from pp data !!

■ global analysis - setup & goals

goal: provide NLO (and LO) D_i^h for $\pi^\pm$, $K^\pm$, p, η, Λ, ...
✓ ✓ in progress

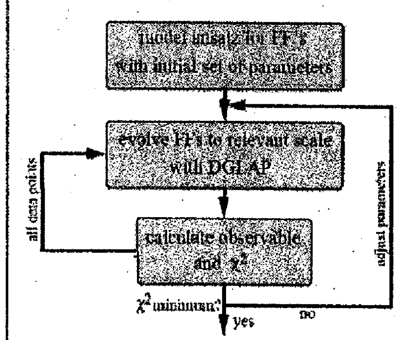
and estimate their uncertainties

analysis method:

- input scale for evolution: μ = 1 GeV
- $D_i(z,\mu) = N z^\alpha (1-z)^\beta [1 + \gamma (1-z)^\delta]$
  for i = u,d,s; i = g, c, b w/o [...],
  allowing for small isospin violations
- 7 parameters for exp. normalizations
- standard χ^2 minimization (MINUIT);
  "Lagrange multiplier technique"
  for studies of uncertainties

Σ 23 parameters

outline of χ^2 analysis:



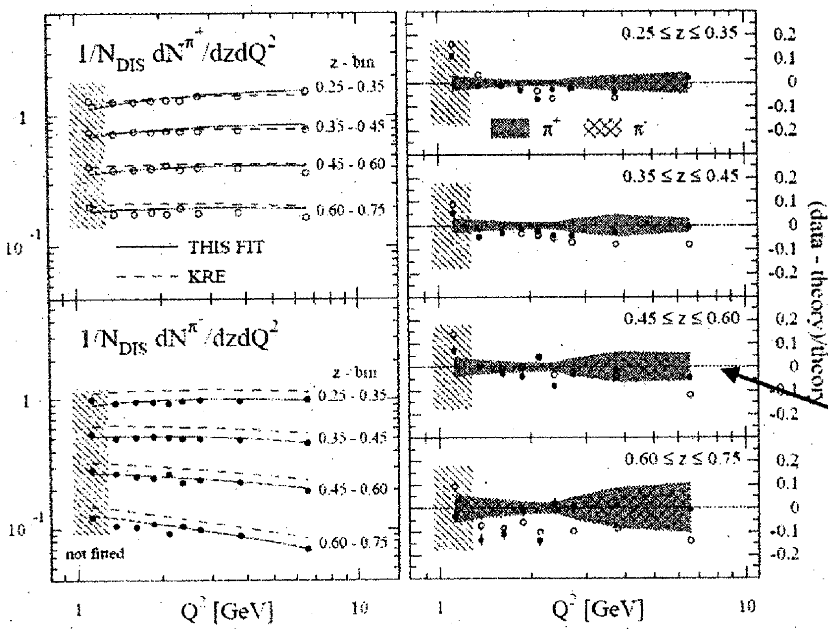
■ comments on data selection

included: all LEP, SLD, TASSO, TPC e^+e^- data w/o "flavor tagging"
[other (= older e^+e^-) data have no impact on the fit]
HERMES SIDIS ep data
BRAHMS, PHENIX, and STAR pp data

reluctantly included: e^+e^- "flavor tagged" data
only constraint on c, b $\rightarrow$ light hadrons
many conceptual problems: strong model dependence;
leading hadron assumptions;
possible contamination from weak decays; ...

excluded: e^+e^- unidentified charged hadron data (work in progress!)
ep photoproduction from H1, ZEUS
[large uncertainties from photon structure;
but known to be consistent with e^+e^- data (xKK)]
UA1 pp data for kaons [inconsistent with STAR]

■ global analysis: results ep semi-incl. DIS



nice description of HERMES $\pi^\pm$ multiplicities

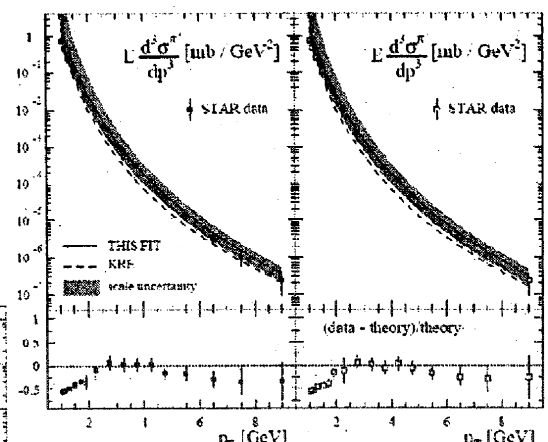
shaded bands: our estimate of "Q^2-bin effects"

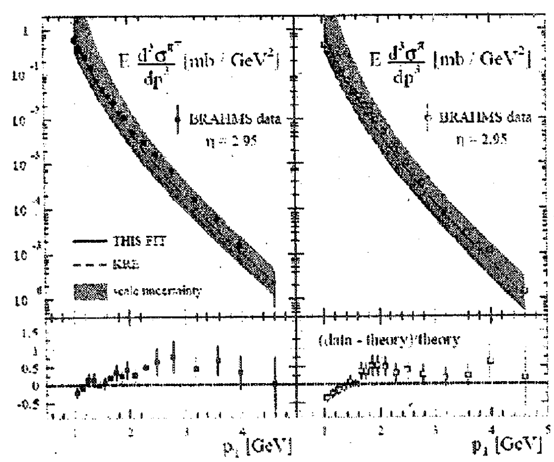
recall: xKK of no use for $\pi^\pm$ data

charge separated data

STAR

(upps, we missed them in the fit)





BRAHMS

uncertainties: method

basically two methods explored for pdf analyses:

pioneering work by CTEQ collaboration

- **"Hessian method"** $[\delta\Delta f]^2 = \Delta\chi^2 \sum_{ij} \frac{\partial \Delta f}{\partial a_i} H_{ij}^{-1} \frac{\partial \Delta f}{\partial a_j}$

  assumes that χ^2-profile is quadratic in all parameters a_i; uncertainties propagate linearly to observables

- **"Lagrange multiplier method"** $\Phi(\lambda_i, a_j) = \chi^2(a_j) + \sum_i \lambda_i O_i(a_j)$

  probes uncertainties in observables O_i *directly*, straightforward to implement

  steps: minimize for $\lambda_i = 0 \rightarrow$ "best fit" with χ_0^2, parameters $a_j^0, O_i(a_j^0)$

  explore χ^2-profile for various fixed $\lambda_i \neq 0$ (=force values of O_i)

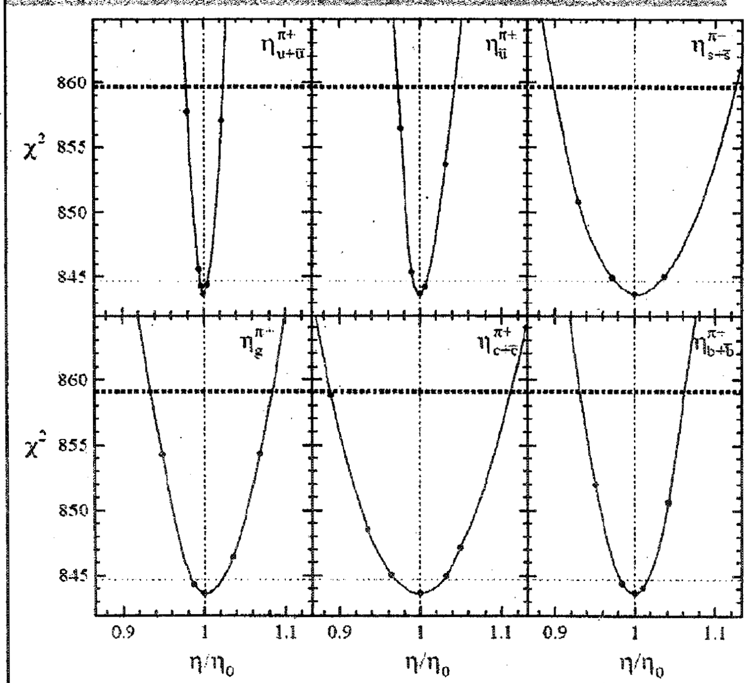
  ideal case: parabolic profiles, $\Delta\chi^2=1$ for 1σ errors

  in practice: unaccounted errors, $\Delta\chi^2 = 1$ - 2% more appropriate

→ our choice: use, e.g., $\eta_i = \int_{0.2}^{1} z\, D_i(z)\, dz$ as "observables"

uncertainties: χ^2-profiles

$\eta_i = \int_{0.2}^{1} z\, D_i(z)\, dz$
$Q = 5$ GeV



overall: almost parabolic χ^2 - profiles

assuming $\Delta\chi^2 \approx 15$

$u_{tot} \rightarrow \pi^+$ constrained best (3% variation)

$u_{sea} \rightarrow \pi^+$: ≈ 5%

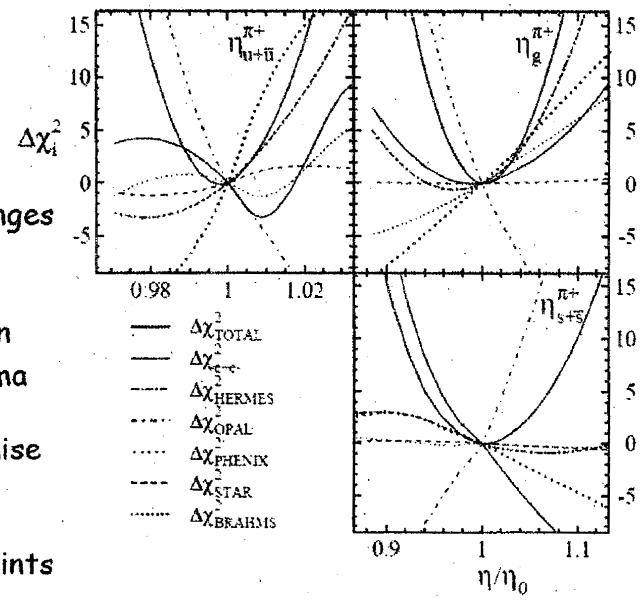
$s \rightarrow \pi^+$: ≈ 10%

$g \rightarrow \pi^+$: ≈ 8%

■ role of different data sets

$\eta_i = \int_{0.2}^{1} z\, D_i(z)\, dz$
$Q = 5$ GeV

study partial contributions to χ^2 from different data sets:



- data sets probe diff. z-ranges and aspects of $D_i(z)$
- complementary information leads to well defined minima
- result is always a compromise
- e^+e^- data alone would lead to different or no constraints

■ final remarks: LO & kaon fits

main results of global analysis of kaon data:

- can achieve a good global description of all e^+e^-, ep, and pp data
- quality of available data not as good as for pions
- STAR and old UA1 pp data cannot be described both (we use STAR)
- **overall:** uncertainties are considerably larger; χ^2 profiles less parabolic

main results of LO fits:

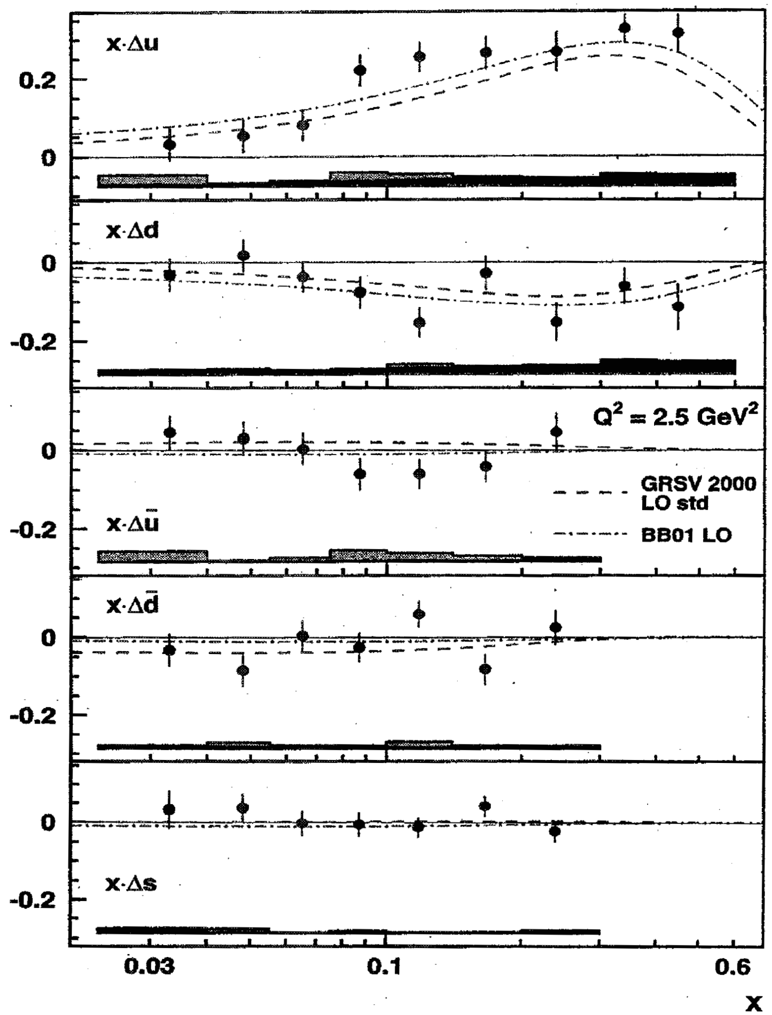
- quality of fit much worse: 25 $\div$ 30% increase in χ^2 w.r.t. NLO
- quarks fairly stable; LO D_g larger (make up for large pp K-factors)
- LO sets should be only used for rough estimates

Semi-inclusive Deep Inelastic Scattering at HERMES and at the proposed EIC

Edward R. Kinney
University of Colorado, Boulder, USA

- HERMES 5 flavor decomposition
- HERMES Isoscaler Δs extraction
- HERMES Future Plans
- EIC Projections

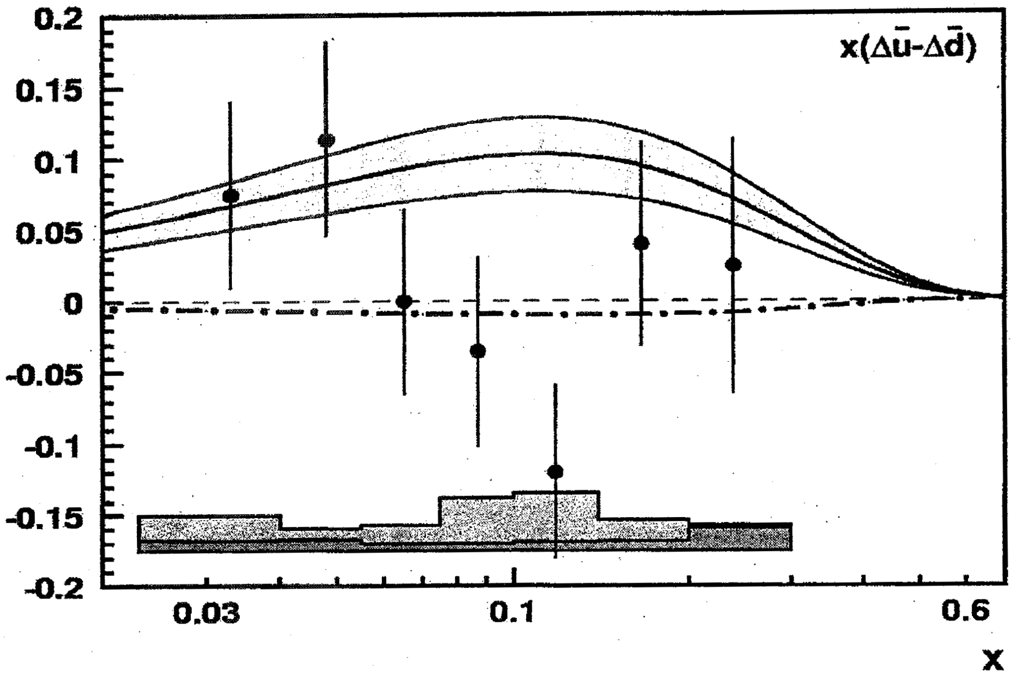
LO Flavor Decomposition: Δq



- "Valence" Δu best determined
- "Valence" Δd less well
- Sea Δq's consistent with zero within large statistical uncertainties
- Δs "favors" positive values but NLO fits to inclusive (e.g. GRSV2000 and BB01) + world semi-inclusive still give small negative value (e.g. de Florian, Navarro, Sassot, *Phys. Rev.* D 71 (2005) 094018).

GRSV2000: *Phys. Rev.* D63 (2001) 094005
BB01: *Nucl. Phys.* B636 (2002) 225

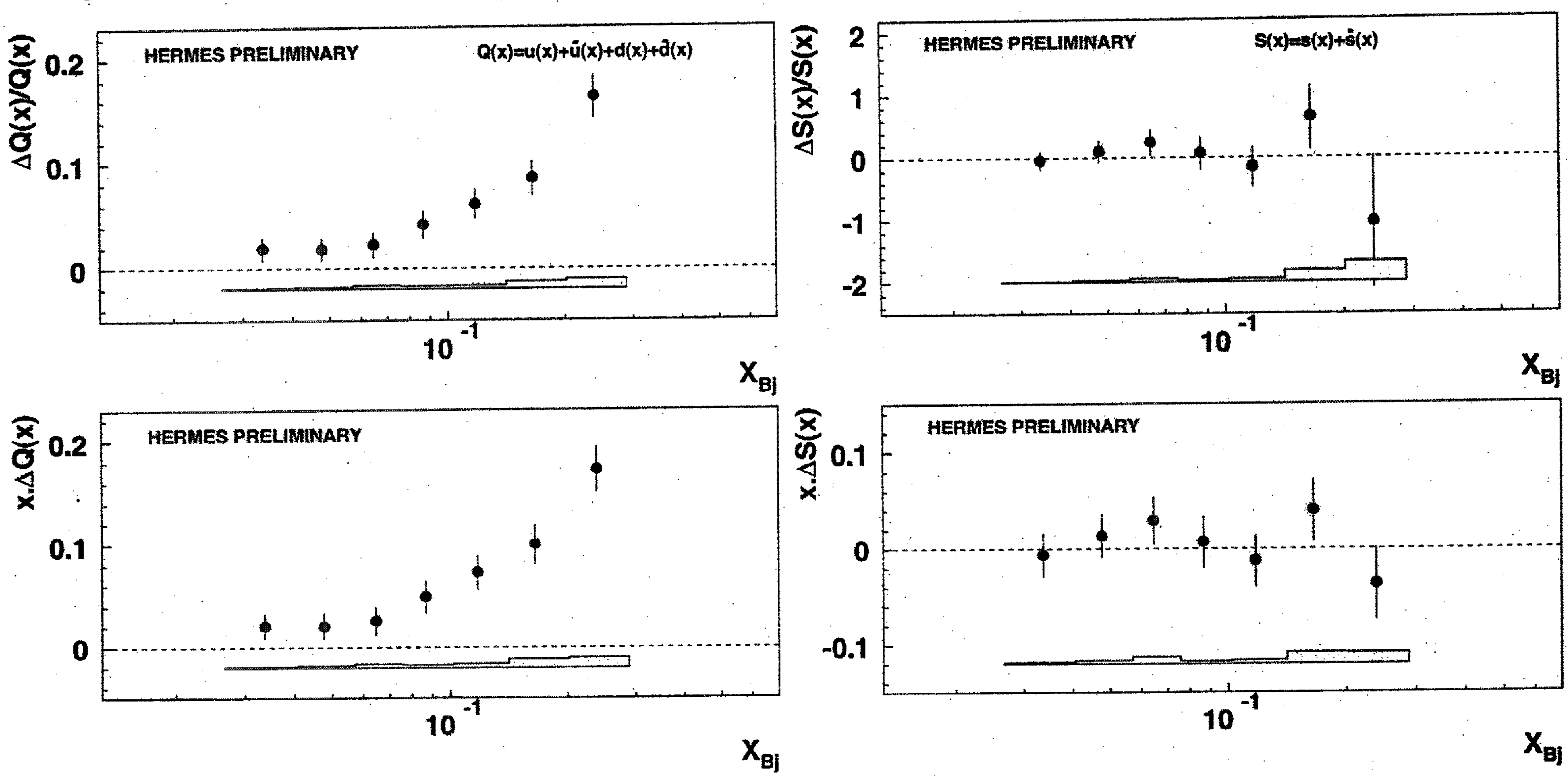
Flavor Asymmetry in the Light Sea



Model Prediction	χ^2/ndf
Meson Cloud Model	8.1/7
Chiral Quark Soliton Model	17.6/7
Symmetric Light Sea	7.7/7

Meson Cloud Model: Cao & Signal, *Phys. Rev.* D 68 (2003) 074002.
Chiral Quark Soliton Model: Dressler *et al., Eur. Phys. J.* C 14 (2007) 147.

Polarizations and Helicity Distributions from Isoscalar Analysis

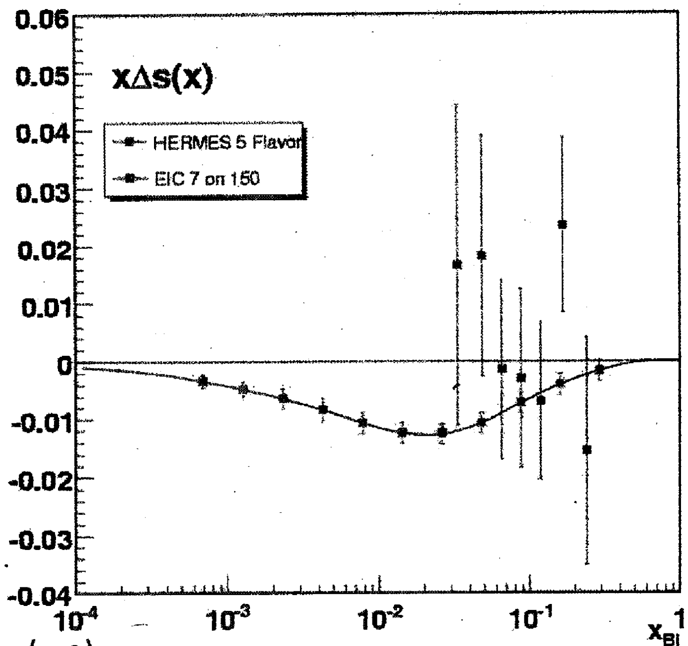


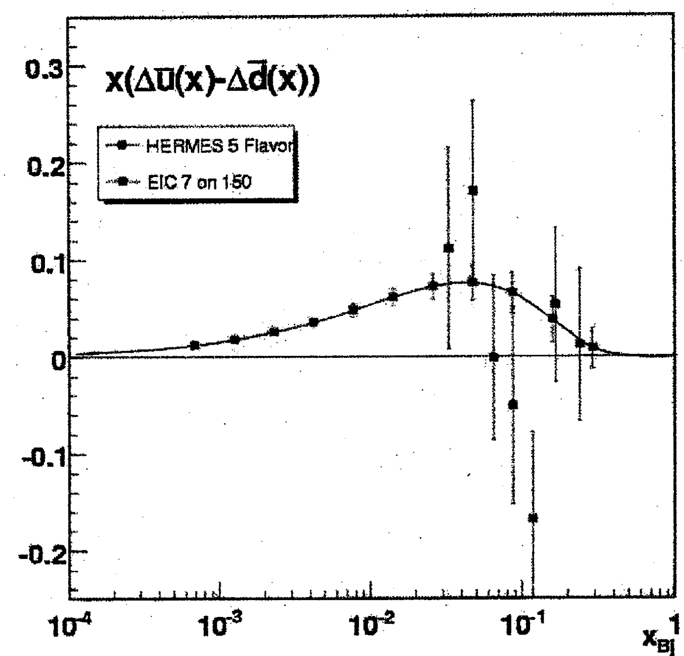
Better determination than 5 flavor, still consistent with zero, but uncertainties are still large relative to (negative) global fit results

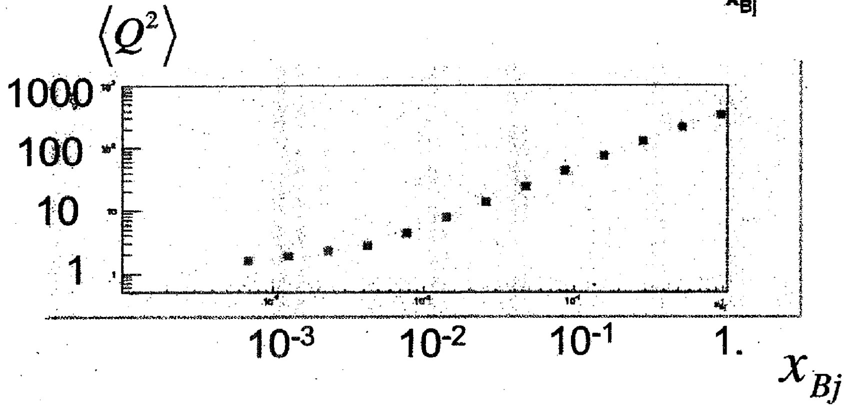
Ongoing HERMES Δq Efforts

- Include additional low momentum identified hadrons from the D target (2-4 GeV/c)
- Include additional hadron asymmetries from H and D data
- Bin/fit asymmetries in z, p_T
- More rigorous study of systematic uncertainties from fragmentation modeling.

7 on 150 EIC Expectations







Curves are GRSV2000

26 April 2007 RIKEN-BNL Workshop

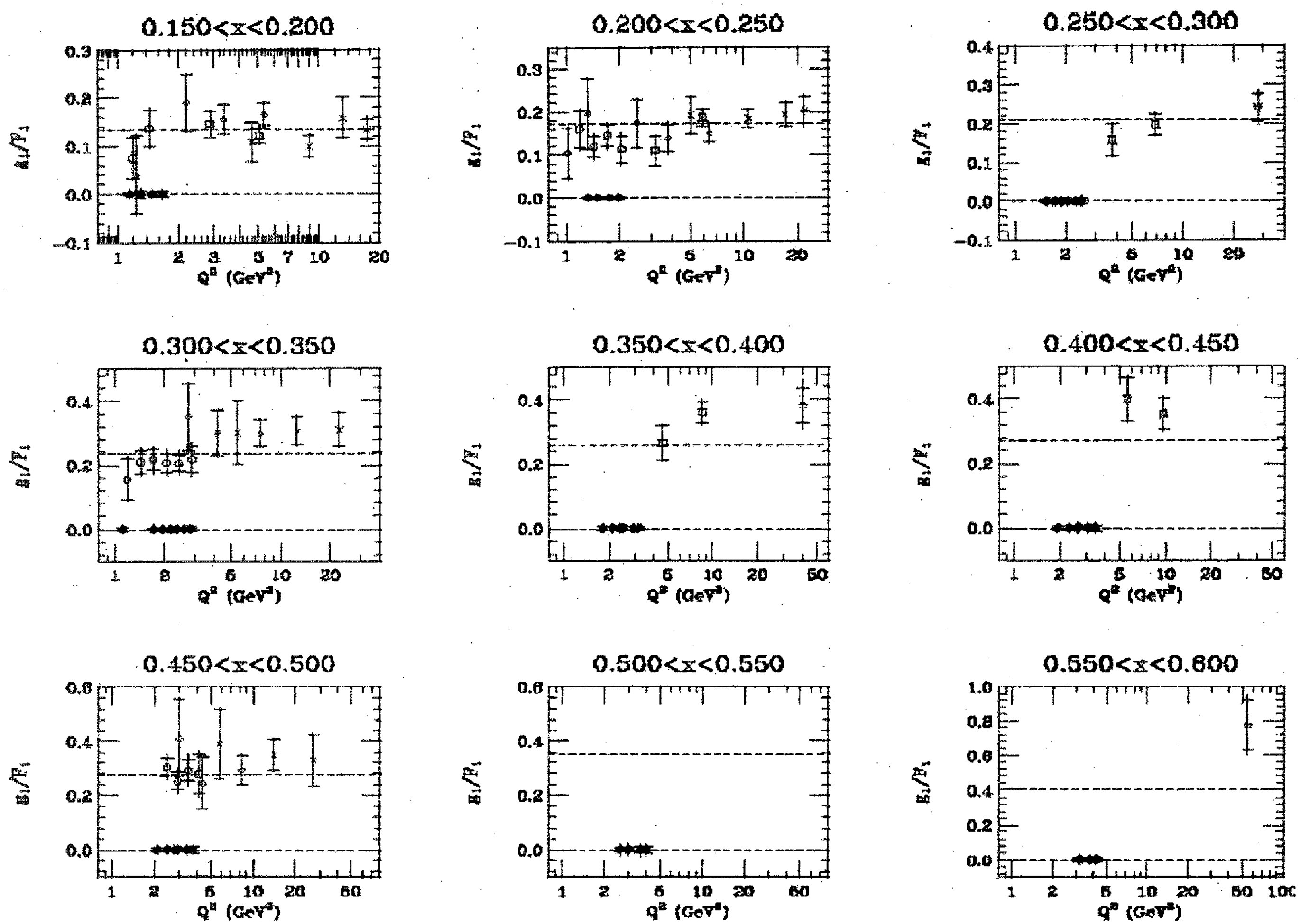
Polarized Parton Distributions and Experiments at Jefferson Lab

Xiaodong Jiang, Rutgers University. April 26, 2007 @ RHIC.

With the high intensity and high polarization electron beam at JLab 6 and 12 GeV, deep inelastic scattering experiments on polarized targets provide new constraints on polarized parton distributions.

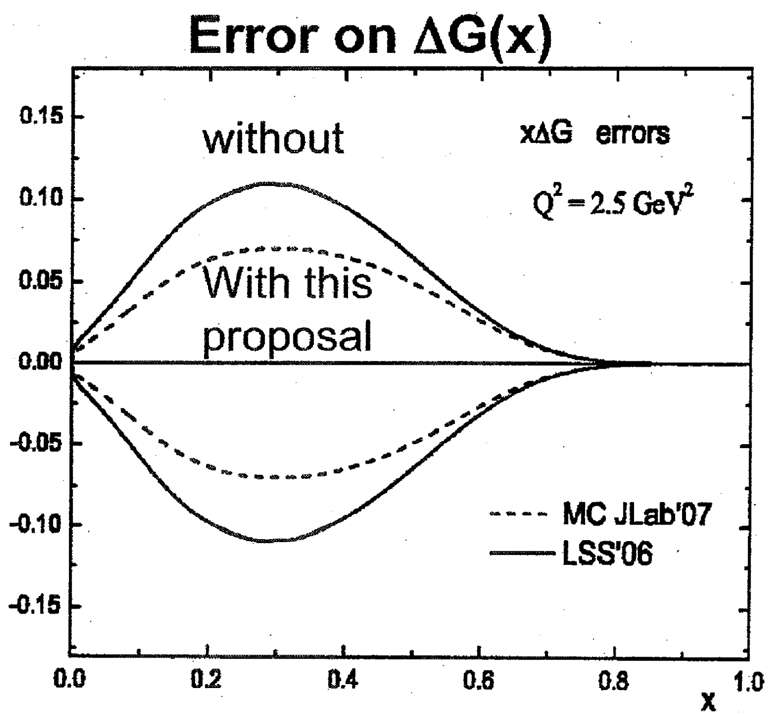
- Inclusive DIS data and constraints on polarized PDF.
  - Measurements of A_{1p}, A_{1d}, A_{1n}(^{3}He) $\Rightarrow \Delta u + \Delta\bar{u}, \Delta d + \Delta\bar{d}$.
  - Constraints on ΔG.
- Semi-inclusive DIS and constraints on polarized PDF.
  - Upcoming experiment: A^h_{1p}, A^h_{1d}, A^h_{1n}(^{3}He) $\Rightarrow \Delta u_v, \Delta d_v, \Delta\bar{u} - \Delta\bar{d}$.
  - More constraints on ΔG.
- JLab 12 GeV upgrade and connections with RHIC-II.

JLab @ 6 GeV: more A_{1d} data to come



Experiment E07-011. P. Bosted, X. Jiang, F. Wesselmann, co-spokespersons.

JLab 6 GeV experiment on A_{1d} will reduce error band on ΔG



- Will collect data in late-2008, share beam time with E04-113.
- Same constrain power on ΔG as of RHIC $A_{LL}^{\pi^o}$ 2006 data (AAC-07).

Constrain Polarized PDF with Semi-Inclusive DIS Data

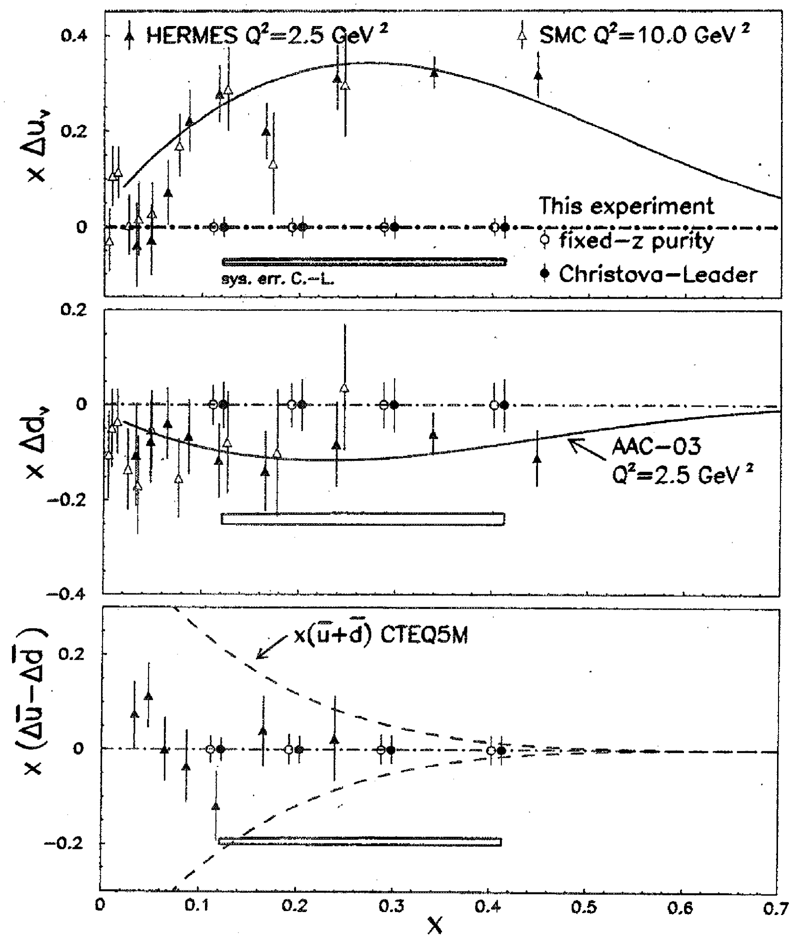
Inclusive DIS data provide constraints on $\Delta q + \Delta \bar{q}$.

In SIDIS, final state hadron tagging separates Δq from $\Delta \bar{q}$ through differences in fragmentation, data provide constraints on $\Delta q - \Delta \bar{q}$.

Measure SIDIS double-spin asymmetries in $\vec{N}(\vec{e}, e'h)$.

- Δq results from HERMES.
- Upcoming JLab experiment E04-113: precision data on A_{1p}^{h} and A_{1d}^{h} .
- Flavor/charge non-singlet combination $\pi^+ - \pi^- \Rightarrow \Delta u_v, \Delta d_v$.
- To obtain $\vec{p} - \vec{n}$: $\Delta u_v - \Delta d_v \stackrel{g_1^p - g_1^n}{\Longrightarrow} \Delta \bar{u} - \Delta \bar{d}$.
- Inputs to NLO global fit to constrain $\Delta q, \Delta \bar{q}$ and ΔG.

E04-113: Expected Results on Δq_v and $\Delta\bar{u} - \Delta\bar{d}$



$$\Delta u_v = \Delta u - \Delta\bar{u}$$
$$\Delta d_v = \Delta d - \Delta\bar{d}$$

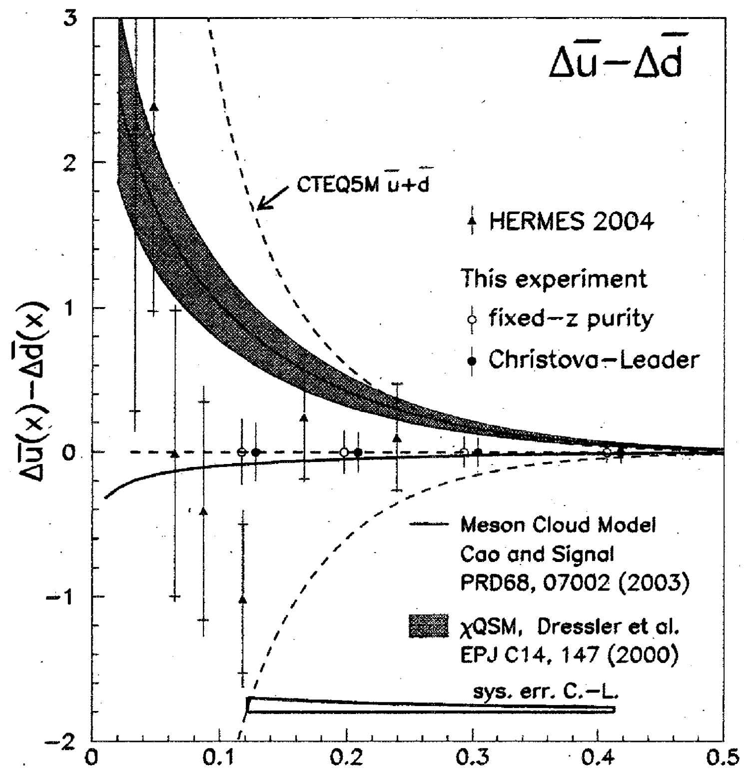
Tow independent methods of flavor decomposition:

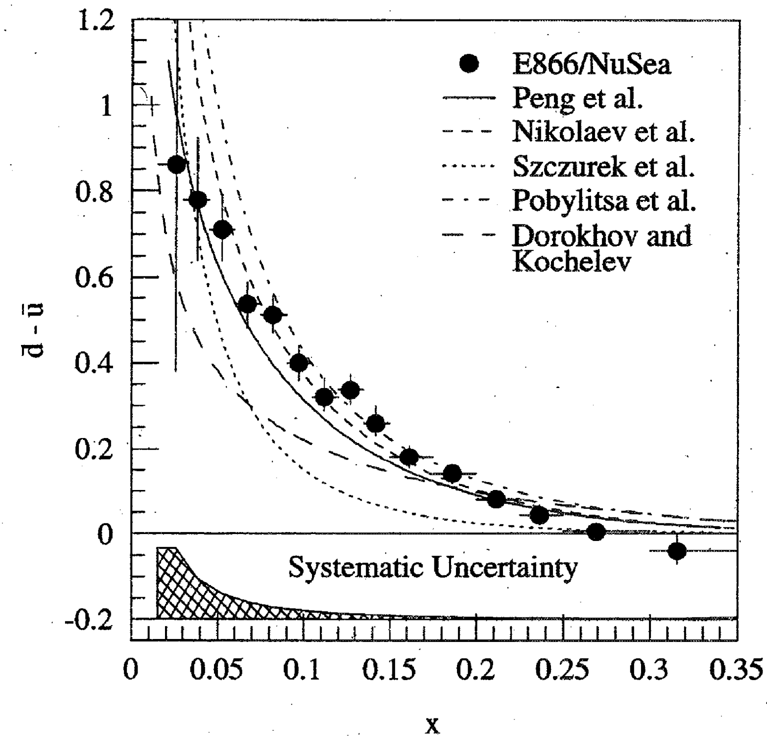
i, Christova-Leader method.

ii, "Purity" at a fixed-z.

One expects at least $\Delta\bar{u} - \Delta\bar{d} > (\bar{d} - \bar{u})$!!!

E04-113: Access Flavor Asymmetry in the Nucleon Sea



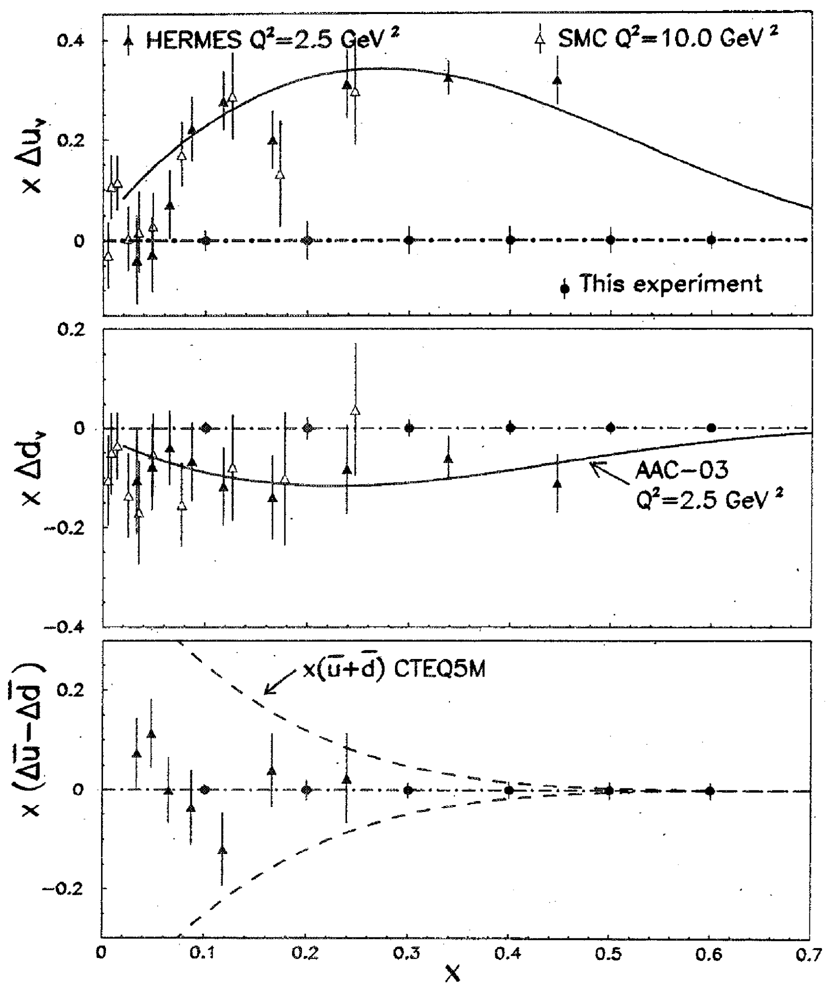


Many other model predicted large $\Delta\bar{u} - \Delta\bar{d}$. In Chiral-quark soliton model, $\Delta\bar{u} - \Delta\bar{d}$ appears in LO (N_c^2) while $\bar{d} - \bar{u}$ appears in NLO (N_c).

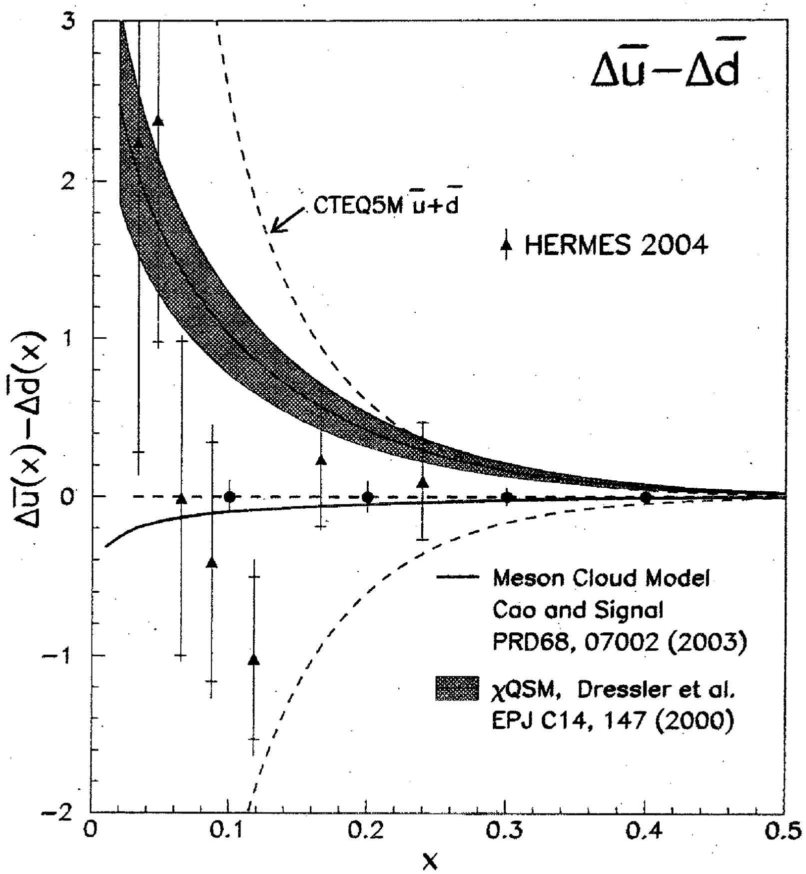
Fermilab $pp, pd \to \mu^+\mu^-$ data. Many models explain $\bar{d} - \bar{u}$, including the meson-cloud model (π) which predicts $\Delta\bar{u} = \Delta\bar{d} = 0$.

Pauli-blocking model: $\int_0^1 [\Delta\bar{u}(x) - \Delta\bar{d}(x)]dx = \frac{5}{3} \cdot \int_0^1 [\bar{d}(x) - \bar{u}(x)]dx \approx 0.2.$

After 12 GeV Upgrade: Spin-Flavor Decomposition through SIDIS



11 GeV beam on NH_3 (1200 hours) and ^{3}He (400 hours) targets.



(X. Jiang, JLab 12 GeV upgrade CD1 report.)

The W program at PHENIX

Workshop on Parity Violating Spin Asymmetries

BNL, April 26-27th

R. Seidl (University of Illinois and RBRC)

for the PHENIX Collaboration

In order to be able to use W production to study the spin and sea structure of the nucleon in PHENIX it is necessary to upgrade the existing muon trigger. The current muon trigger just detects muon candidates but in the future 500GeV RHIC running the muon rate will be dominated by low P_T heavy quark decays while muons from W decays dominate at higher transverse momenta. It is therefore necessary to create a momentum sensitive trigger to predominantly select high-P_T muons. PHENIX has two fully funded upgrades which will accomplish this. The current front end electronics of the Muon tracker will be upgraded to also allow a fast readout of the tracking information and in addition three planes of resistive plate counters per muon arm will be installed to add further rejection of low-P_T muons. The muon trigger upgrade is currently in transition from the design to the construction phase and a first trigger will be ready in 2009.

For the offline analysis of the W data samples the background has to be reduced further which can be achieved using additional information from other upgrades such as the Nose Cone Calorimeter and the Forward VerTeX detector.

PHENIX

Motivation for W physics I: sea polarization

- Parity violating decay selects quark flavor:

$$A_L^{W^+\to\mu^+\nu_\mu} = \frac{\Delta u(x_a)\bar{d}(x_b) - \Delta\bar{d}(x_a)u(x_b)}{u(x_a)\bar{d}(x_b) + \bar{d}(x_a)u(x_b)}$$

- Forward/backward region selects valence/sea quark helicity contribution

$$x_a >> x_b \Rightarrow u(x_a) >> u(x_b), \bar{d}(x_b) >> \bar{d}(x_a)$$

$$\Rightarrow A_L^{W^+\to\mu^+\nu_\mu} \approx \frac{\Delta u(x_a)\overline{d(x_b)}}{u(x_a)\overline{d(x_b)}}$$

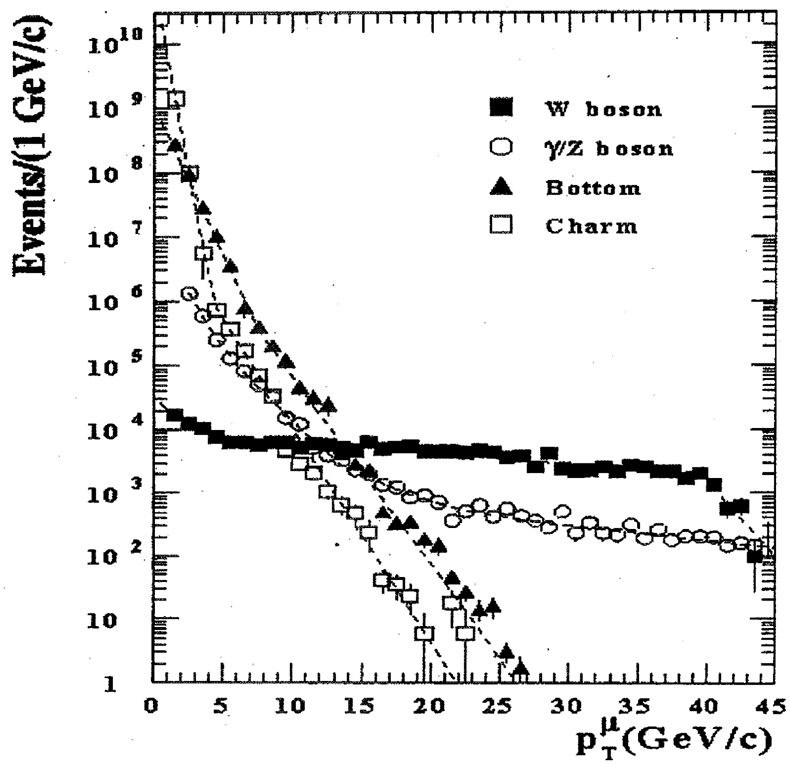
- High luminosity and high $\sqrt{s}$=500 GeV needed
- Only $\mu^\pm$ detected → control of backgrounds important
- High energy muon trigger necessary

Advantages of W as probe:

- Large Scale ($\sim m_W$)
- no Fragmentation functions required

PHENIX Necessity of muon trigger upgrade

Inclusive μ Production, 500 GeV/c



- Hadronic decays dominate muon rates
- W dominate only above 20-25 GeV
- DAQ cannot take full rate @500GeV
- Current muon trigger momentum "blind"

➔ Need for a momentum sensitive muon trigger

➔ Add Resistive Plate Counters(RPCs)

➔ Add fast readout electronics for Muon tracker

PHENIX muon trigger upgrade

(I) Three dedicated trigger RPC stations (CMS design):

RPC1(a,b): ~180 segments in φ, 2 in θ

RPC2: ~360 segments in φ, 2 in θ

RPC3: ~360 segments in φ, 2 in θ

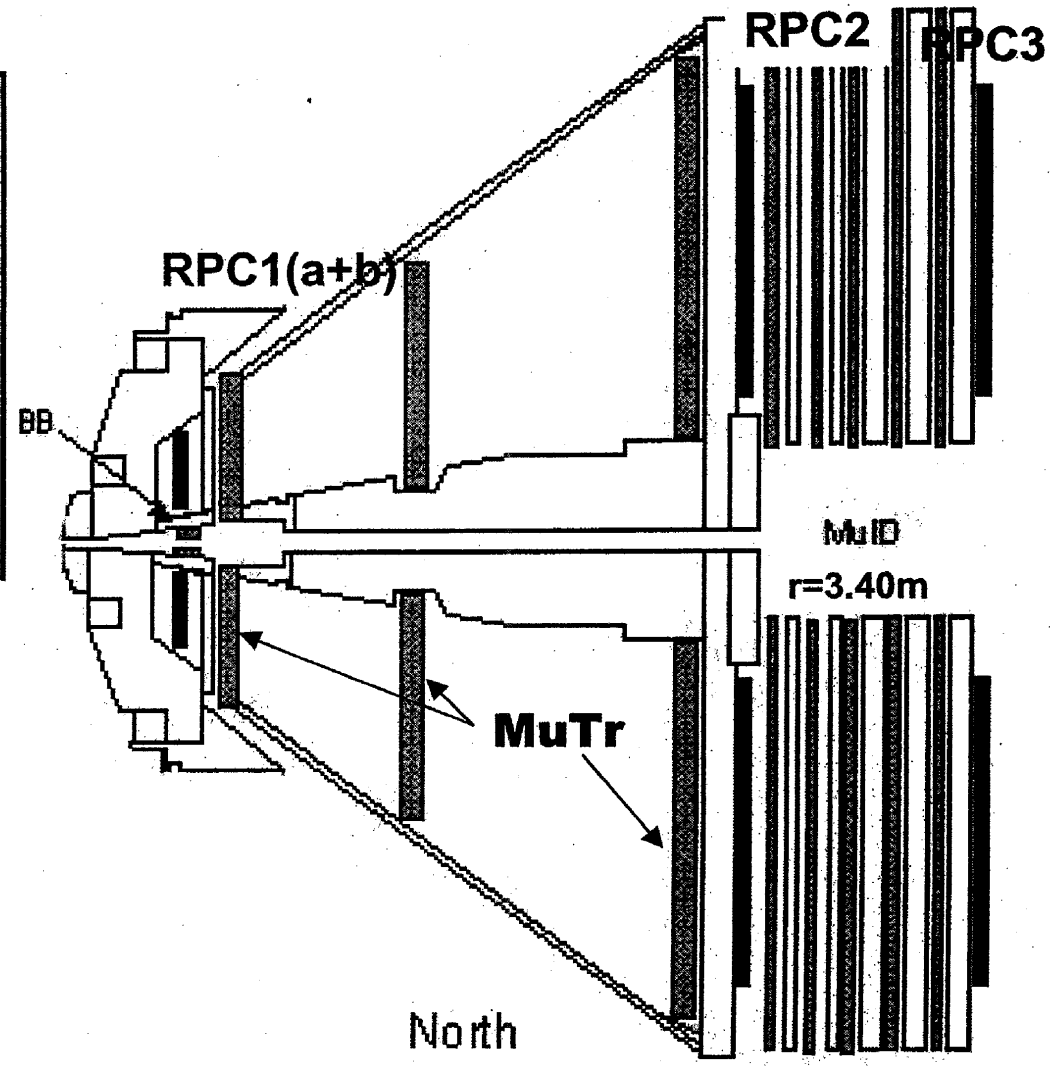
(Trigger only – offline segmentation higher)

NSF (Funded)

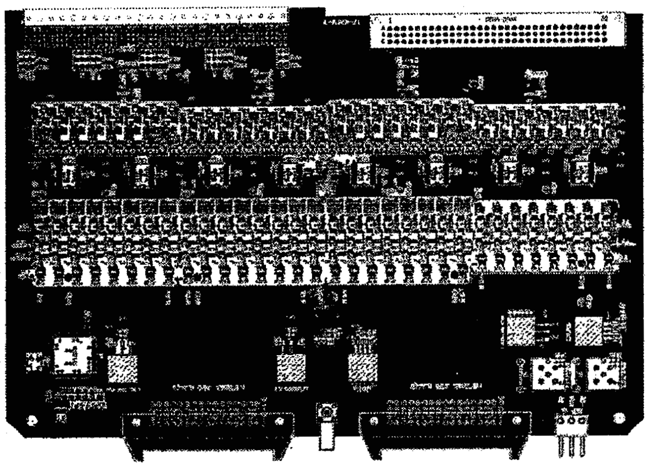
(II) MuTr front end electronics

Upgrade to allow LL1 information

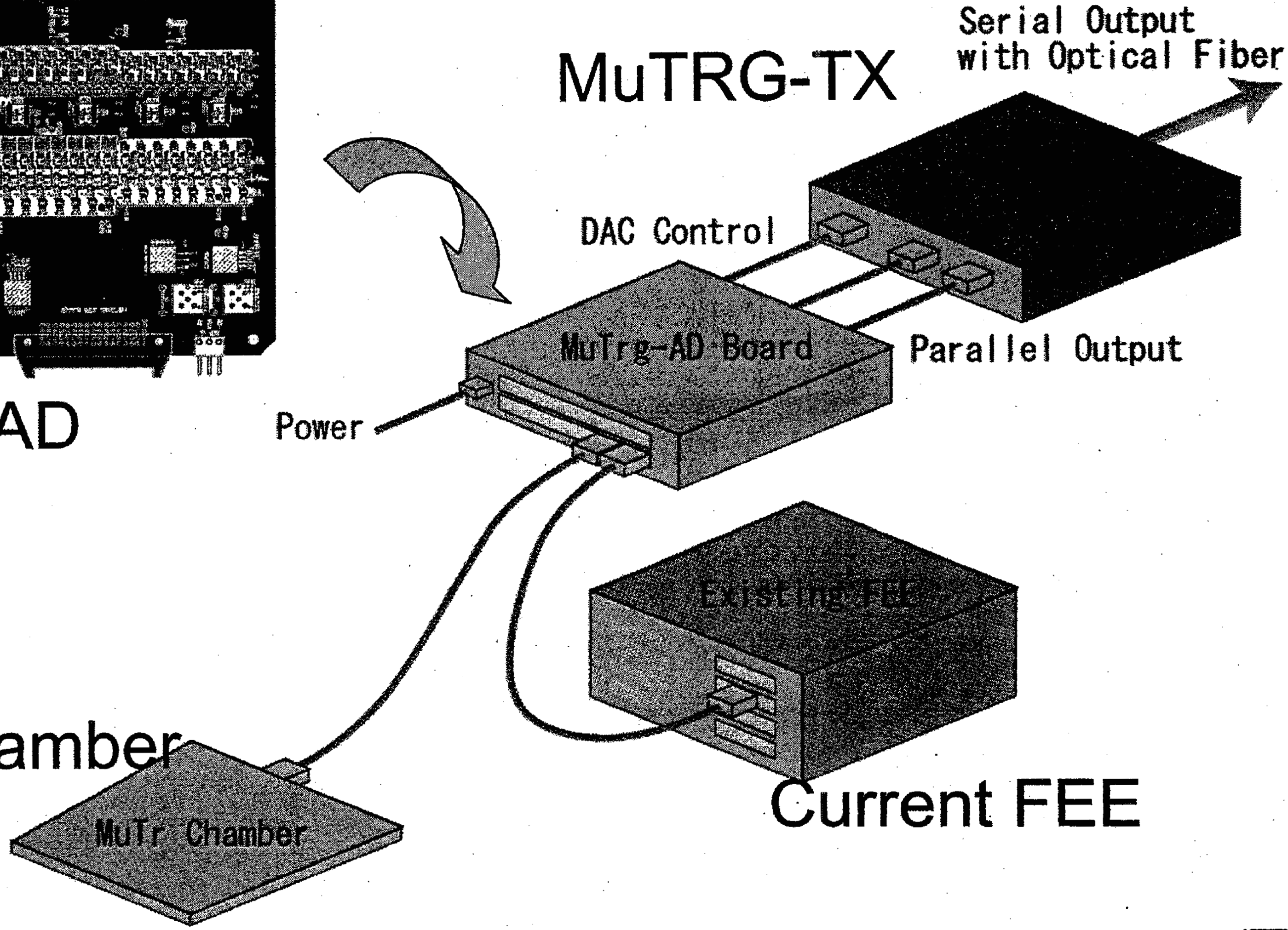
JSPS (Funded)



PHENIX New MuTRG Front End Electronics(FEE)



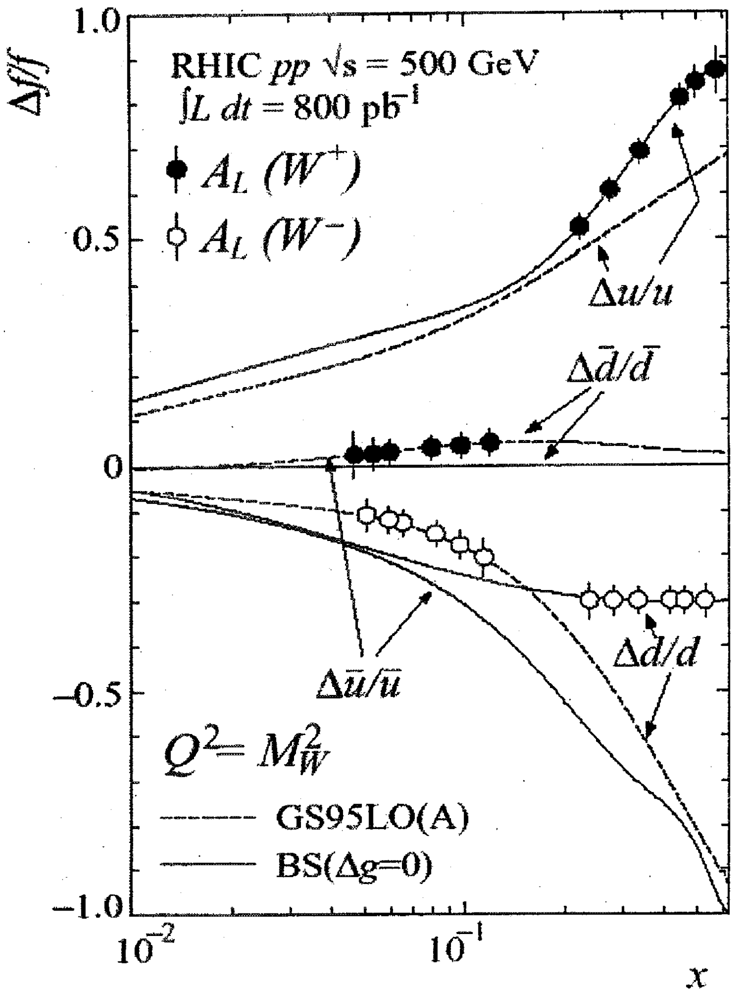
MuTRG-AD



74

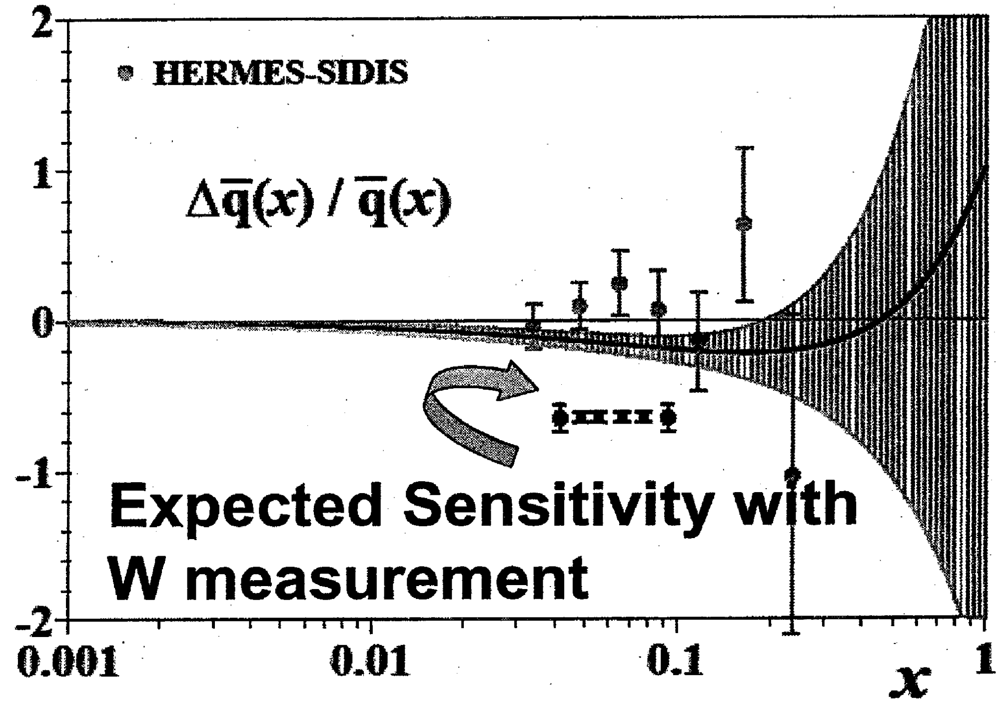
PHENIX

PHENIX $A_L^{W+/-}$ Sensitivity

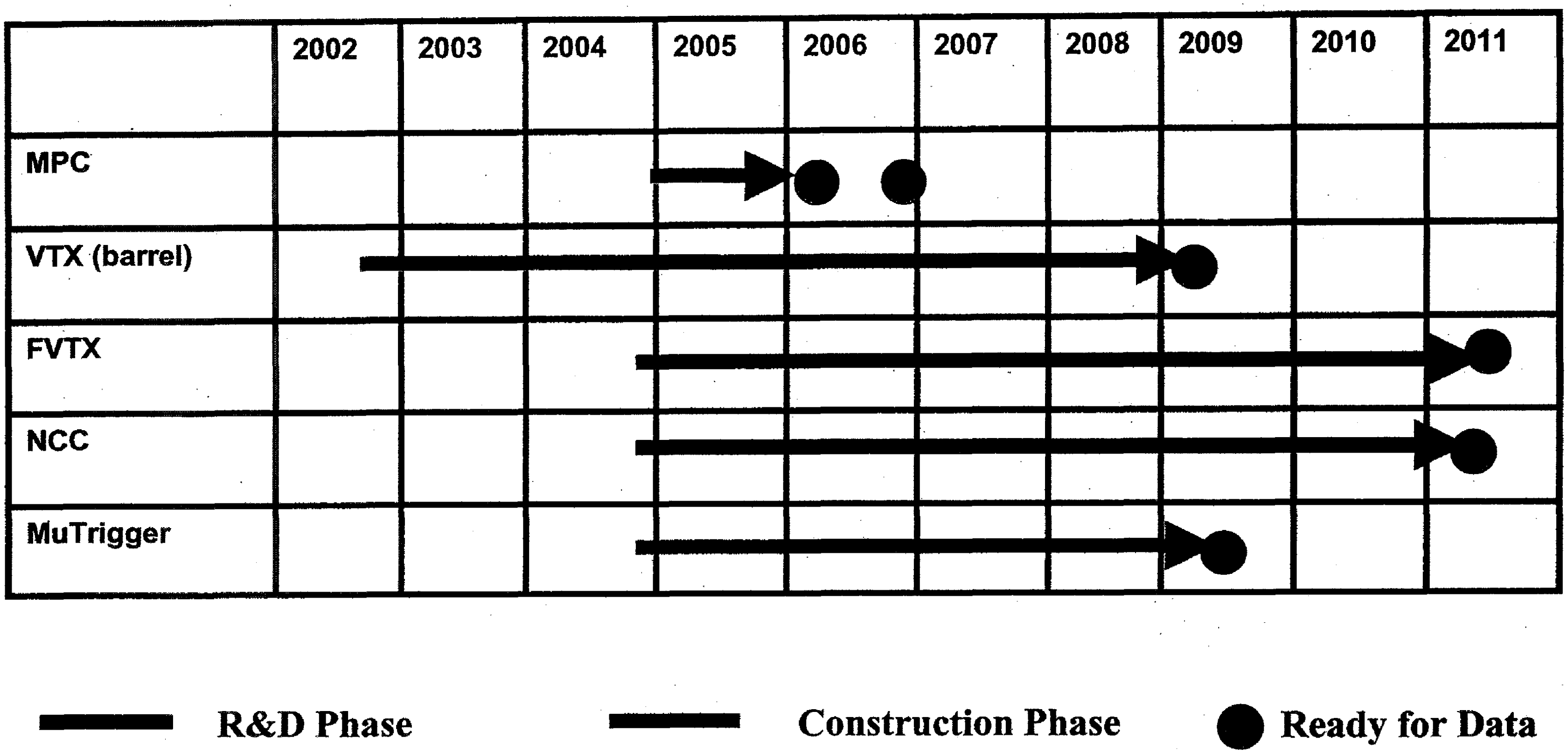


- **Machine and detector requirements:**
  - $\int Ldt=800pb^{-1}$, P=0.7 at $\sqrt{s}$=500 GeV
  - Muon trigger upgrade!

2009 to 2012 running at $\sqrt{s}$=500 GeV is projected to deliver $\int Ldt \sim 980pb^{-1}$



Upgrade Schedule



Plans & Prospects for W Physics with STAR

Frank Simon, M.I.T. for the STAR Collaboration

The study of flavor-separated polarized quark distributions in the proton is one of the cornerstone measurements of the RHIC-Spin program with polarized proton collisions at 500 GeV. This measurement is possible using the intrinsic spin and flavor sensitivity of maximally parity violating W boson production.

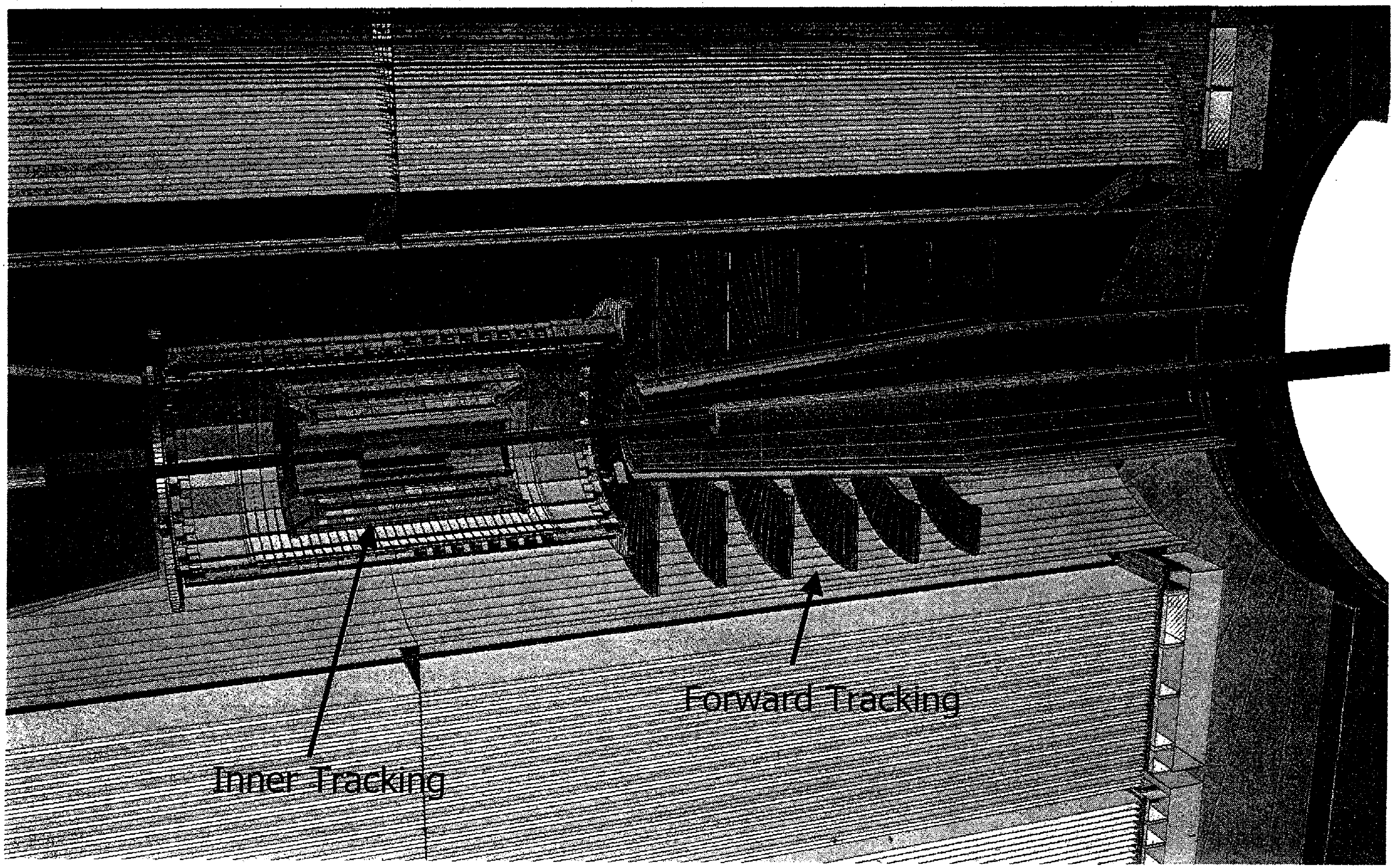
At STAR $W^{-(+)}$ bosons will be detected through their electron (positron) decay mode. The experimental signature of these W decays is a high-pt lepton. These electrons are detected in the large acceptance electromagnetic calorimeters of STAR, the Barrel EMC (BEMC), $-1 < \eta < 1$, and the Endcap EMC (EEMC), $1 < \eta < 2$. The calorimeter signals are also used to trigger on W events. Since the QCD background of charged particles is several orders of magnitude larger than the leptonic signal, clean electron-hadron separation is mandatory. This will be achieved through a shower-shape analysis of calorimeter data, exploiting the existing pre-shower, shower-maximum and post-shower layers in the calorimeters. Additional discrimination power is provided by E/p cuts on the charged tracks, by imposing an isolation cut on the electron candidate and by a missing p_t cut.

The sensitivity of W production at RHIC is greatest at forward rapidities, $1 < \eta < 2$. This range is covered by the EEMC in STAR. However, to distinguish the charge sign of the W, and thus identify the flavors of the quarks involved in its creation, charge sign identification of the outgoing lepton is crucial. In the forward region of STAR there is currently no precision tracking available to provide this charge sign identification. An upgrade of the forward tracker in STAR is currently being planned, which has been successfully presented during the January BNL Detector Advisory Committee. The committee strongly suggested to move forward with this STAR upgrade project on an aggressive time scale. Simulations have shown that a spatial resolution of ~80 μm is necessary to correctly identify the charge of electrons with transverse momenta of up to 40 GeV/c. This will be achieved with 6 large-area triple GEM disks installed along the beam axis, covering the acceptance of the EEMC. This Forward GEM Tracker (FGT) will have an outer radius of approximately 43 cm and an inner radius of around 12 cm, varying with the position of a given disk. The FGT is designed to cover the full extend of the interaction diamond of +- 30 cm.

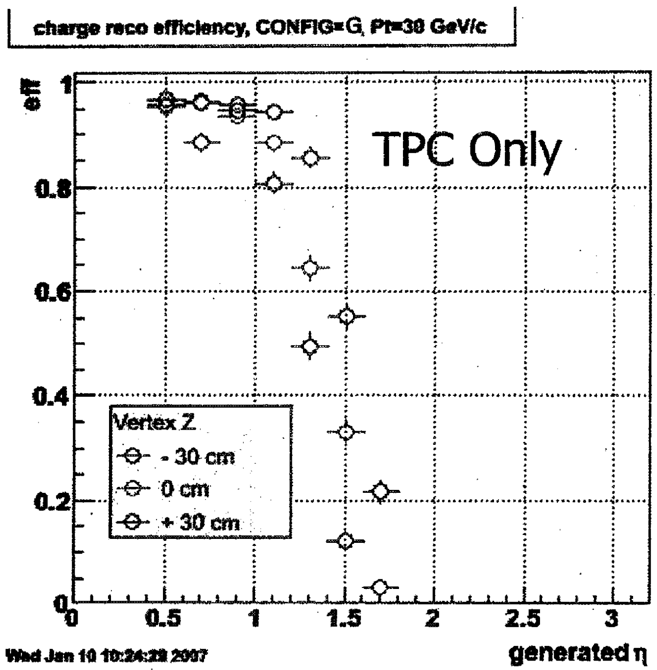
Triple GEM detectors provide high spatial resolution and high rate capability with a low material budget of less than 1% X_0 per layer providing a 2D space point. They are ideal to cover large areas with precision tracking at moderate cost. The GEM detectors in STAR will be using GEM foils produced by Tech-Etch Inc. of Plymouth, MA. In a collaboration between Tech-Etch, BNL, MIT and Yale commercial GEM foil production is being established at Tech-Etch, funded through a Phase II SBIR proposal. The FGT will use front-end electronics based on the APV25-S1 chip developed for the CMS experiment at the LHC. The mechanical structure is based on low-mass materials, such as carbon fiber, carbon foam and honeycomb structures. The total project costs for the forward tracking upgrade are below $2M, allowing an accelerated construction schedule. With a total construction time of about 1 year after the initial R&D and design phase the FGT is planned to be operational for the FY2010 RHIC run.

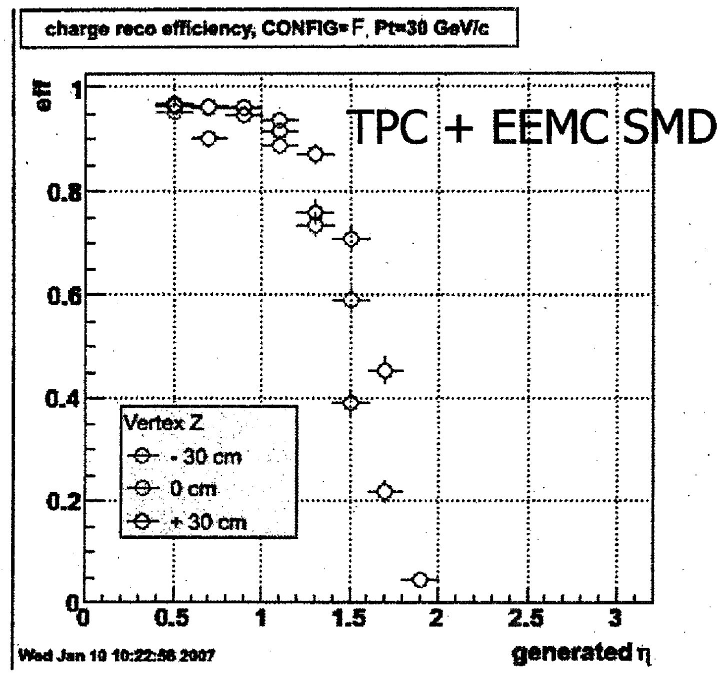
Currently the quality of Tech-Etch produced GEM foils is being studied and optimized. First test results demonstrate a quality comparable to the CERN reference foils and stable operational characteristics. A first beam test of prototype detectors using Tech-Etch foils and the full APV25-S1 readout chain is scheduled for the beginning of May 2007.

Forward Tracking: Baseline Design I



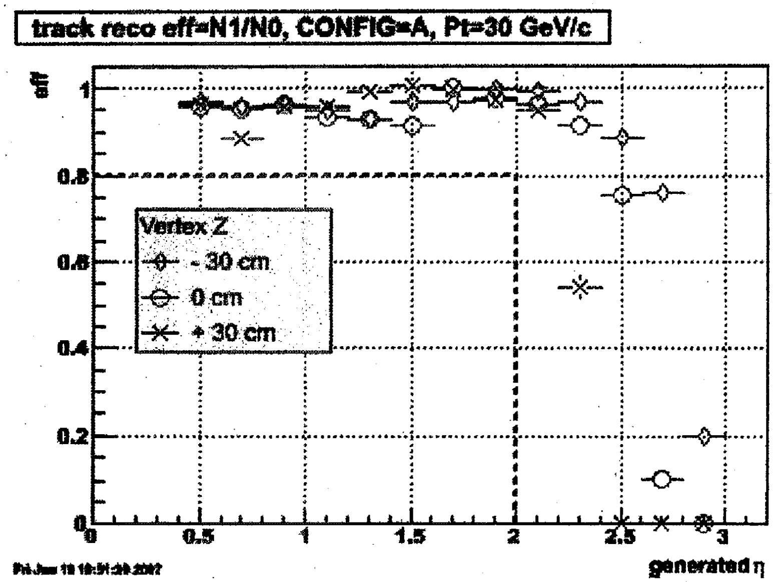
Simulations: Present Capabilities

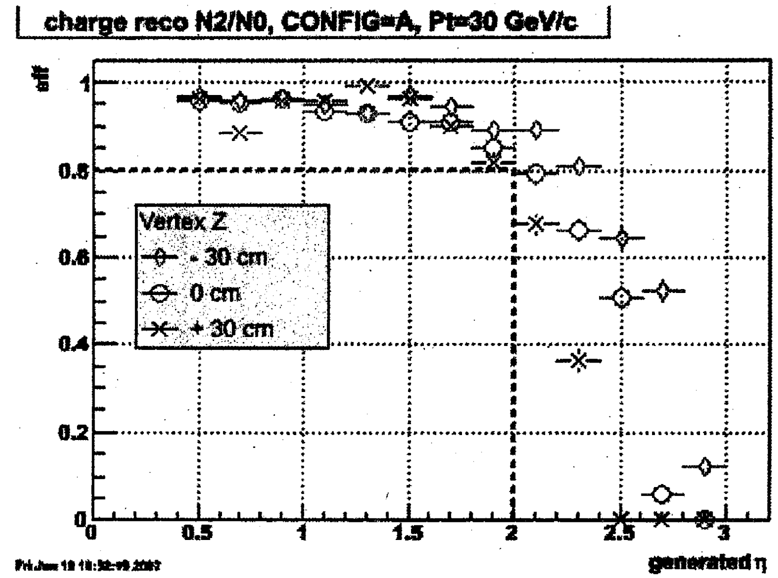




- Spatial resolution of the EEMC SMD: ~1.5 mm
- Charge sign reconstruction impossible beyond η = ~1.3

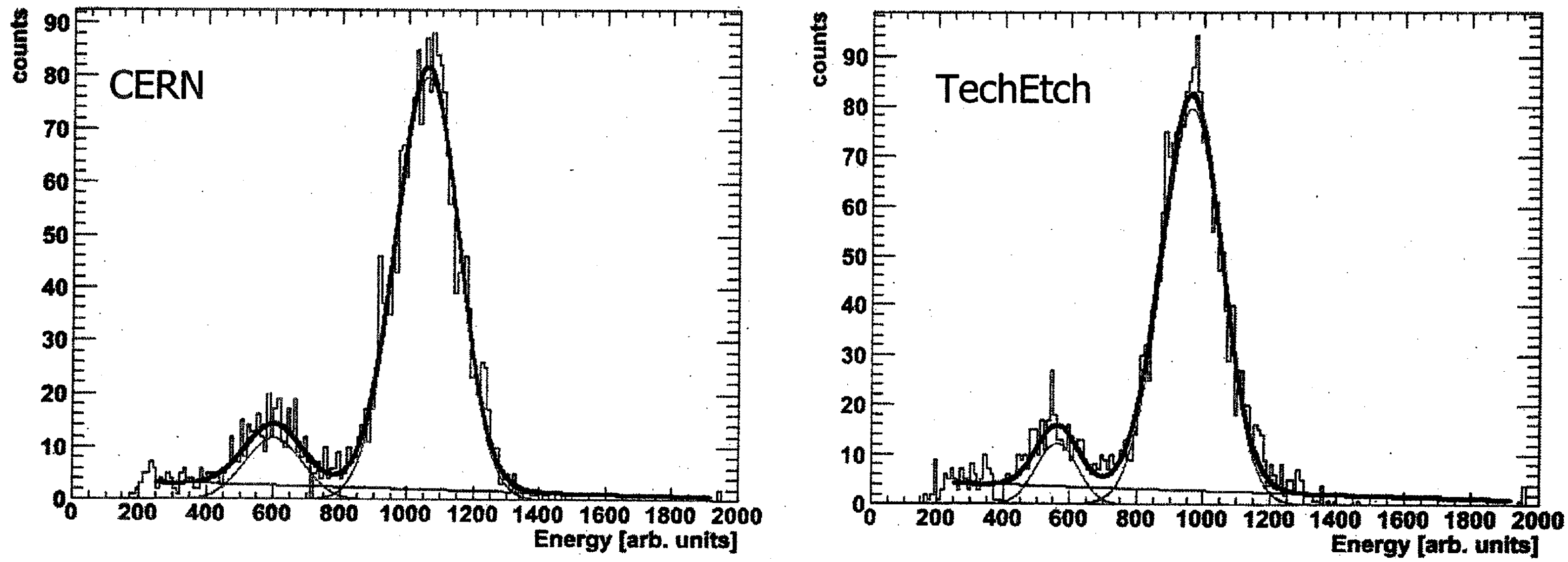
Simulations: Baseline Design





- 6 triple-GEM disks, assumed spatial resolution 60 μm in x and y
- charge sign reconstruction probability above 80% for 30 GeV p_T over the full acceptance of the EEMC for the full vertex spread, >90% out to $\eta = 1.8$
- the addition of two high-resolution silicon disks does not provide significant improvement and is thus not considered further
- 4 GEM disks might be sufficient, but the added redundancy of 6 disks comes at low cost

^{55}Fe Tests



- Triple GEM test detectors are tested with a low intensity ^{55}Fe source (main line at 5.9 keV)
- Both Detectors (based on CERN and on Tech-Etch foils) show similar spectral quality and energy resolution (~20% FWHM of the Photo Peak divided by peak position)

Construction Schedule

- Design phase (Support structure / Triple-GEM chambers): 12 weeks
- Procurement of material: 6 weeks
- Construction of detector quarter sections: 18 weeks
  - Delivery of 10 GEM foils from Tech-Etch per week
  - Test of GEM foils (Electrical tests, optical scan on flatbed scanner): 0.5 week
  - Test of readout board (Parallel to GEM foil tests): 0.5 week
  - Construction of GEM detectors: Mechanical assembly, foil mounting, testing between each gluing step: 2 weeks
  - Test of assembled chamber: Gas tightness, X-ray test, Gain map: 2 weeks
  - Estimated total construction of one quarter section: 5 weeks
  - Assume: 2 detectors in parallel starting every week
- Construction of full system: 10 weeks
  - Assemble 6 disks on support frame from 4 quarter sections each: 1 week
  - Assemble electrons and test: 2 weeks
  - Test disk electrons and detectors and full system test (Cosmic ray test): 7 weeks
- Installation: 3 weeks
- Integration: 5 weeks

⇨ total construction time: ~54 weeks

⇨ Aim for Installation for FY2010 run, total project costs below $2M

The Measurement of W's at the CERN and FNAL hadron colliders

- W's at RHIC !
- W's at CERN - UA2
- W's at FNAL - CDF

Michael Rijssenbeek
Stony Brook University

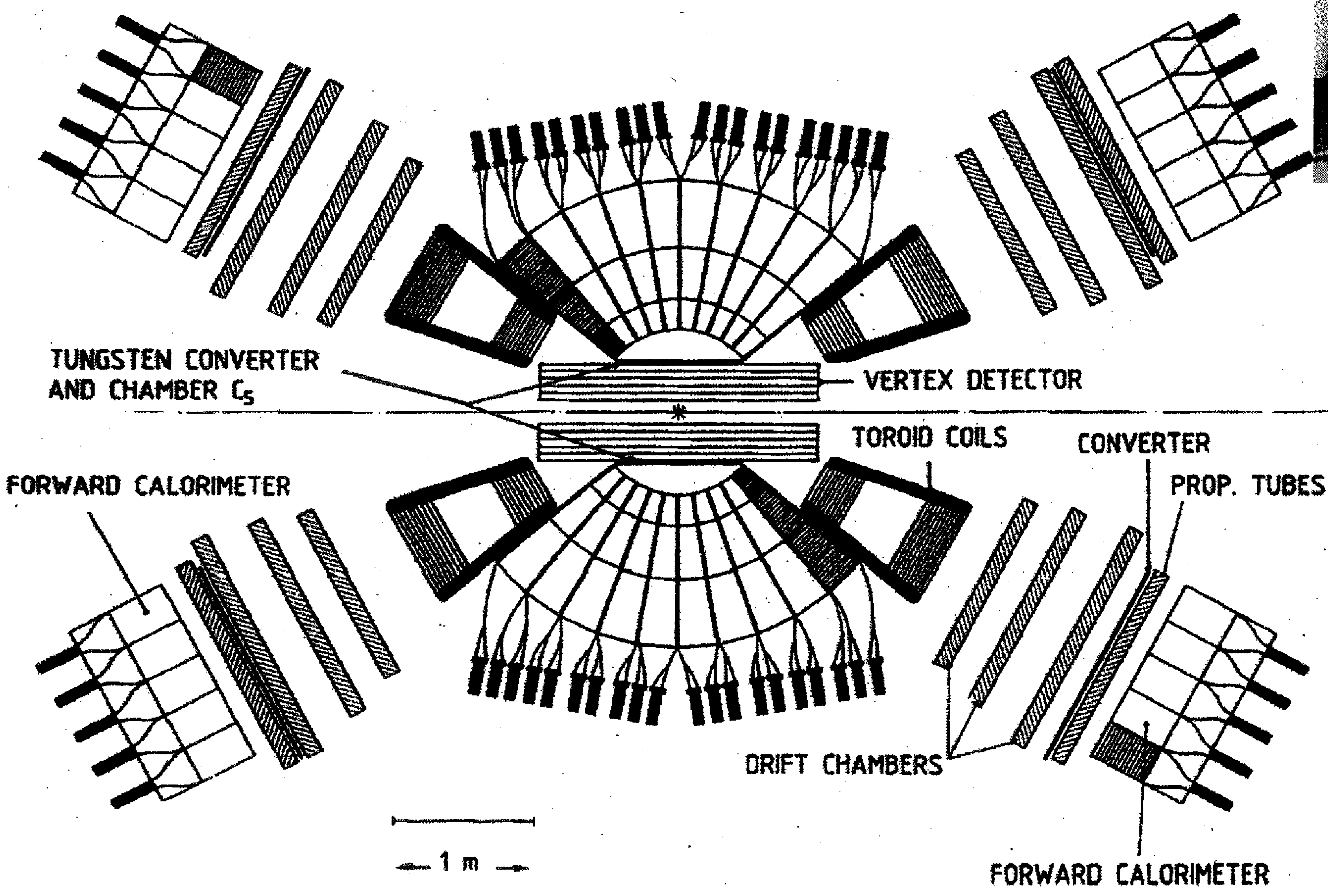
Non-Hermetic Detectors

- RHIC detectors are not fully hermetic…
- electron and muon acceptance of the RHIC detectors varies strongly over the rapidity range…
- Thus:
  - missing transverse energy cannot be used to clean up the W signal
  - Trigger has to rely exclusively on high p_T electrons and muons
  - The backgrounds to the W from $Z \rightarrow e/\mu$ and QCD/fakes may be significant
  - enough Z-statistics for measurement/tuning of corrections?

- Detailed simulations will be crucial to determine acceptance corrections, efficiencies, and backgrounds
  - limited Z acceptance makes tuning of the simulations with $Z \rightarrow ee/\mu\mu$ more difficult

a "Non-Hermetic" Detector: UA2 - vs.1

- Central tracking + Preshower + EM Calorimetry: $|\eta|<1$
- Forward spectrometer + PS + EM Calorimetry: $1<|\eta|<3$



a non-hermetic detector…

UA2 collaboration: M Banner *et al.*, Phys. Lett. 122B (1983) 476.

UA2 collaboration: P Bagnaia *et al.*, Phys. Lett. 129B (1983) 130.

Simulations

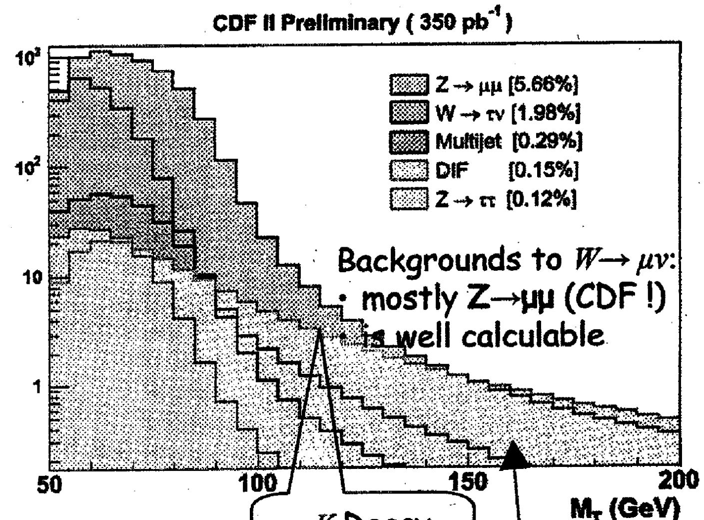
- the state of simulations of W and Z production (and decay) has much advanced over the past decades
  - forced by very high statistics W/Z samples for mass determination from LEP and Tevatron
  - much QCD calculational progress
  - improved detector simulations: showering
  - availability of raw computing power allows more detail and increased sophistication
- State-of-the-Art:
  - RESBOS: NLO W and Z production
  - CTEQ6M: NLO pdf's with uncertainties

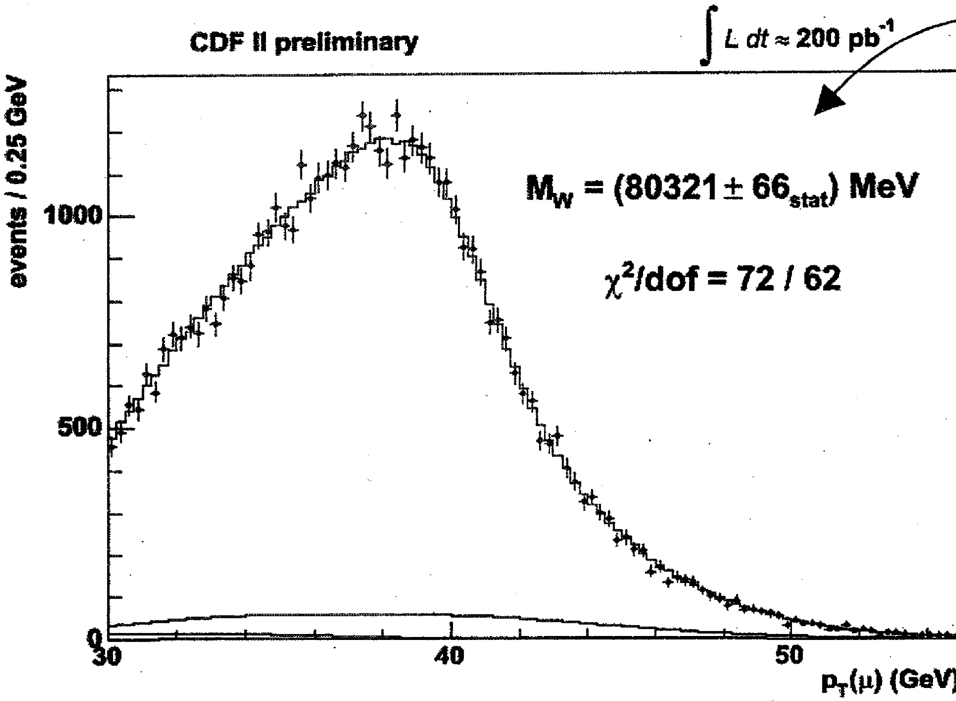
    Note: $p_T^{e/\mu}$ is quite sensitive to boson recoil

    M_T less so, but is sensitive to $y^{W/Z}$
- CRUCIAL for all precision W/Z measurements

CDF W Mass 2007:

- sample size analyzed: 200/pb
- event selection: $p_T^{e,\mu}>30$ GeV, $p_T^{\nu}>30$ GeV
- Uncertainties in M_W for fit to $p_T^{e/\mu}$:





CDF II preliminary L = 200 pb^{-1}

p_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	17	17	17
Recoil Resolution	3	3	3
$u_{\parallel}$ Efficiency	5	6	0
Lepton Removal	0	0	0
Backgrounds	9	19	0
$p_T(W)$	9	9	9
PDF	20	20	20
QED	13	13	13
Total Systematic	45	40	35
Statistical	[illegible]	[illegible]	
Total	73	77	35

My Conclusions

- A precise measurement of Δu and Δd will bring new understanding of the spin structure of the baryons…

- <u>However:</u>
  in order to obtain the required precision, the measurement will need sophisticated simulations to understand and model the detector acceptance, efficiencies, and backgrounds
  - the physics and detector models must be tuned and checked with measurements of the Z (<10% of W statistics)
  - Dominant backgrounds must be measured with the data itself

these simulations must be done *beforehand* to prove the measurement capability with RHIC's "non-hermetic" detectors…

Threshold Resummation for W-Boson Production at RHIC

A. Mukherjee*

Physics Department,

Indian Institute of Technology Bombay,

Powai, Mumbai 400076, India.

Abstract

We study the resummation of large logarithmic perturbative corrections to the partonic cross sections relevant for the process $pp \to W^{\pm}X$ at the BNL Relativistic Heavy Ion Collider (RHIC). At RHIC, polarized protons are available, and spin asymmetries for this process will be used for precise measurements of the up and down quark and anti-quark distributions in the proton. The corrections arise near the threshold for the partonic reaction and are associated with soft-gluon emission. We perform the resummation to next-to-leading logarithmic accuracy, for the rapidity-differential cross section. We find that resummation leads to relatively moderate effects on the cross sections and spin asymmetries.

*Electronic address: asmita@phy.iitb.ac.in

Threshold Resummation for $W^{\pm}$ Production at RHIC

Asmita Mukherjee
Indian Institute of Technology, Mumbai, India

- Threshold logarithms
- Resummation of threshold logs
- Inverse transformation and matching
- Numerical results for RHIC

In collaboration with Werner Vogelsang (BNL)

AM and W. Vogelsang PRD 73, 074005 (2006)

Threshold Logarithms

• NLO : $q\bar{q}' \to W^{\pm}g$ and $qg \to W^{\pm}q'$ contribute

• Corrections near 'partonic threshold' : when the initial partons have just enough energy to produce $W^{\pm}$: $z = M_W^2/\hat{s} \to 1$

• Phase space for real gluon emission vanishes; virtual corrections fully allowed

• Cancellation of singularities between real and virtual diagrams give large logarithmic 'Sudakov' corrections to $q\bar{q}$ cross section

• Interplay of the steeply falling pdfs with the partonic cross sections : Partonic threshold can make a significant contribution to the cross section even if the hadronic process is relatively far from threshold i.e. $\frac{M_W^2}{S} << 1$; RHIC : not far from threshold

• If $M_W^2/S \sim 1$, threshold region completely dominates the cross section ($\sqrt{S} = 200$ GeV at RHIC

•Sufficiently close to threshold : perturbative series is only useful if large logs is taken into account to all orders in α_s : resummation.

Resummed Cross Section

To NLL accuracy, one finds

$$\int_0^1 dz\, z^{N-1} \int_{-\ln\frac{1}{\sqrt{z}}}^{\ln\frac{1}{\sqrt{z}}} d\hat{\eta}\, \mathrm{e}^{iM\hat{\eta}}\, x_1 x_2 D_{q\bar{q}}^{\mathrm{res}}\left(x_1, x_2, x_1^0, x_2^0, \alpha_s(\mu^2), \frac{M_W^2}{\mu^2}\right)$$

$$= \quad \exp\left\{C_q\left(\alpha_s(\mu^2), \frac{M_W^2}{\mu^2}\right) + 2\ln\bar{N}\, h^{(1)}(\lambda) + 2h^{(2)}\left(\lambda, \frac{M_W^2}{\mu^2}\right)\right\},$$

where $\lambda = b_0\alpha_s(\mu^2)\ln\bar{N}$, b_0 is constant

Contributions from quark-gluon channels down by $1/N$: will be included at NLO level

C_q collects mostly hard virtual corrections

$h^{(1)}$ contains LL and $h^{(2)}$ contains NLL terms

Resummation in Mellin space, inverted and matched with NLO

Used 'minimal' expansion of the resummed exponent

- S. Catani, M. L. Mangano, P. Nason and L. Trentadue, Nucl. Phys. B **478**, 273 (1996)

– p.5/10

Inverse Transformation and matching

- Final step : take the Mellin and Fourier inverse transforms of $\Delta\tilde{\sigma}(N, M)$

$$\frac{d\Delta\sigma^{\mathrm{res}}}{d\eta} \quad = \quad \frac{1}{2\pi}\int_{-\infty}^{\infty} dM\, \mathrm{e}^{-iM\eta}\, \frac{1}{2\pi i}\int_{C-i\infty}^{C+i\infty} dN\, \tau^{-N}\, \Delta\tilde{\sigma}^{\mathrm{res}}(N, M)$$

- Choose the contour of integration

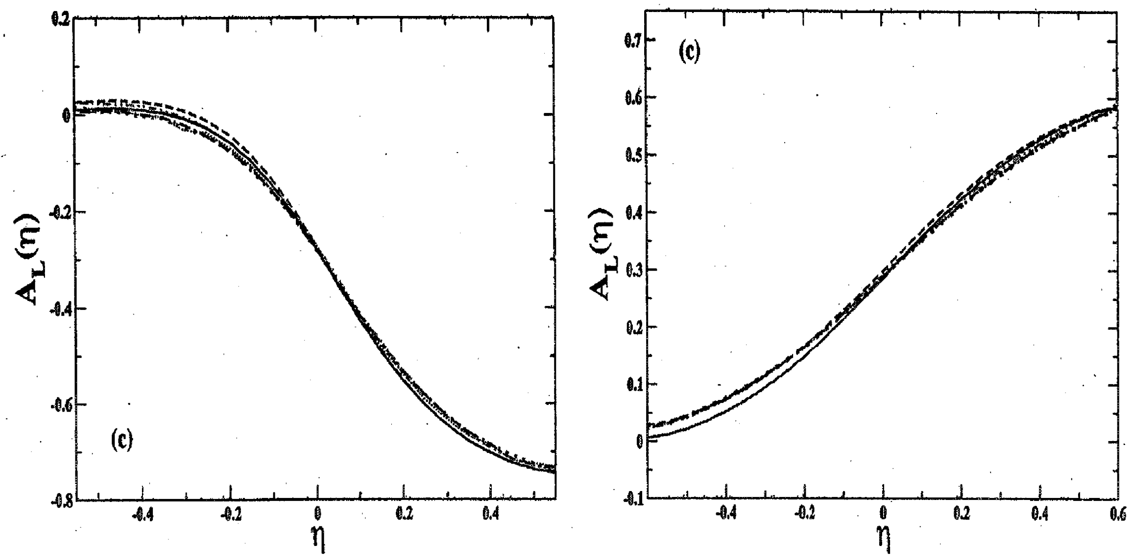
G. Sterman and W. Vogelsang, JHEP **0102**, 016 (2001)

- To keep the full information contained in the NLO calculation, perform a 'matching" of the NLL resummed cross section to the NLO :
Subtract from the resummed expression its $\mathcal{O}(\alpha_s)$ expansion,

$$\frac{1}{2\pi}\int_{-\infty}^{\infty} dM\, \mathrm{e}^{-iM\eta}\, \frac{1}{2\pi i}\int_{C-i\infty}^{C+i\infty} dN\, \tau^{-N}\left[\Delta\tilde{\sigma}^{\mathrm{res}}(N, M) - \Delta\tilde{\sigma}^{\mathrm{res}}(N, M)\Big|_{\mathcal{O}(\alpha_s)}\right],$$

- Then add full NLO cross section.

A_L at RHIC ($\sqrt{S} = 200$ GeV)



- LHS : A_L vs η for W^+ production, RHS : for W^- production
- Resummation effects again, cancel almost entirely in A_L

Summary and Conclusions

- Performed resummation of potentially large 'threshold" logarithms that arise when the incoming partons have just sufficient energy to produce the W boson.
- Considered resummation to next-to-leading logarithmic accuracy for the rapidity dependence of the cross sections
- We find that the resummation effect on the unpolarized and single-longitudinally polarized cross sections is rather moderate at RHIC's higher energy $\sqrt{S} = 500$ GeV, but more significant at $\sqrt{S} = 200$ GeV where one is closer to threshold.
- Shapes of the W rapidity distributions are rather unaffected by resummation.

Future possibilities for W physics (Charm-associated W-boson production at RHIC)

Hiroshi Yokoya*

Department of Physics, Niigata University,
Niigata 950-2181, JAPAN

April 27, 2007

Abstract

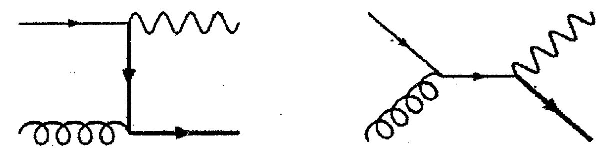
We studied the charm-associated W-boson production in $\vec{p}p$ collisions at RHIC. In spite of the tiny cross section, the process is expected to have a profit to access the strange-quark distribution in the proton. We studied the single longitudinal-spin asymmetry for this process in the leading order of QCD. The asymmetries in y_W distribution and $y_W - y_c$ distribution are estimated, and found that the polarized $\bar{s}$-quark distribution may be probed in the forward W production for the $W^+\bar{c}$ production, however, for the W^-c production, the asymmetry comes dominantly from the polarized d-quark distribution through the Cabibbo mixing.

*E-mail address: yokoya@nt.sc.niigata-u.ac.jp

Charm-associated W-boson production

in collaboration with K. Sudoh (KEK)

$$\vec{p} + p \to W^{\pm} + c(\bar{c}) + X$$

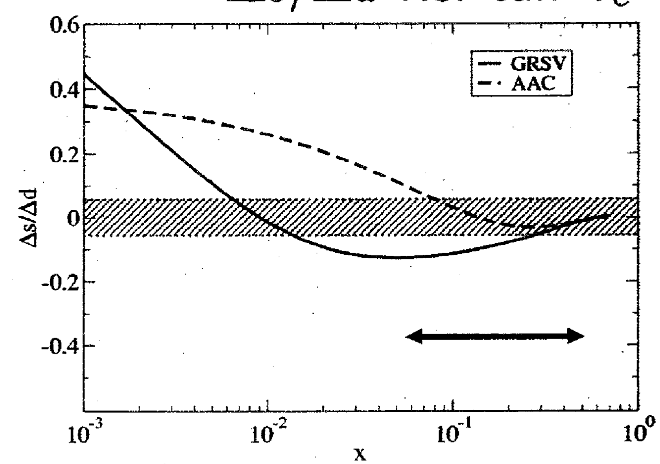


• sub-process in LO : $s' + g \to W^- + c$

$\bar{s}' + g \to W^+ + \bar{c}$

← information on the s-quark pol. PDF

$\Delta s/\Delta d$ v.s. $\tan^2\theta_c$



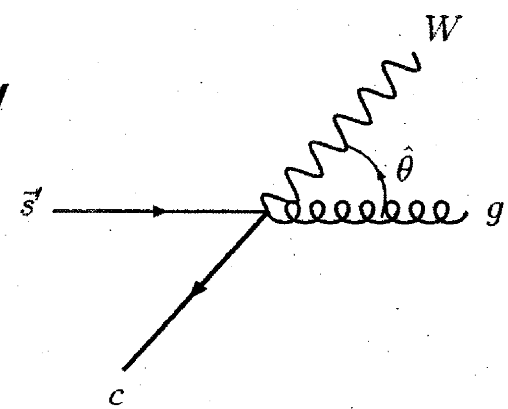
• Cabibbo mixing :

$$s' = \cos^2\theta_c \cdot s + \sin^2\theta_c \cdot d$$

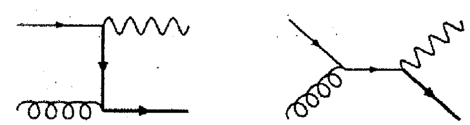
$\theta_c \sim 13°$: Cabibbo angle

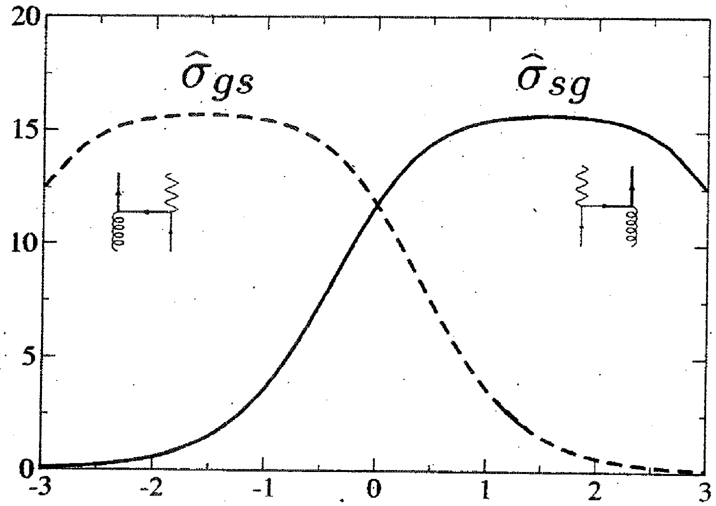
$\tan^2\theta_c \sim 0.056$

Partonic cross-section, partonic asymmetry

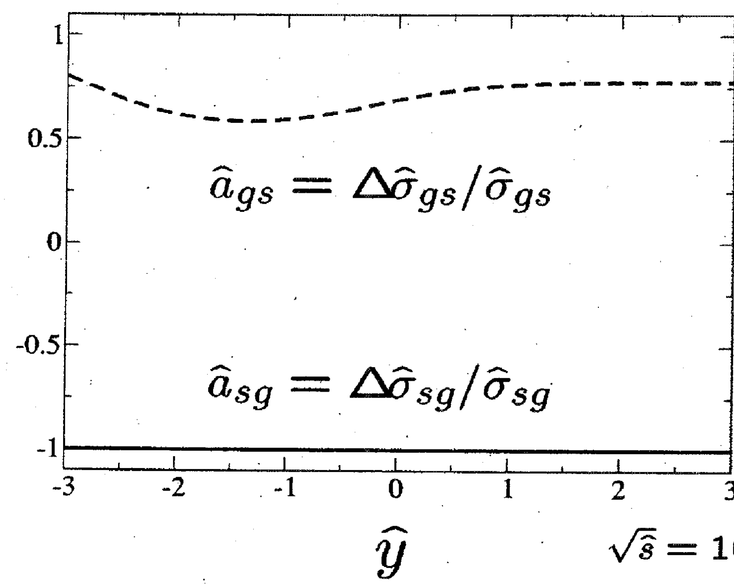


Feynman diagrams;



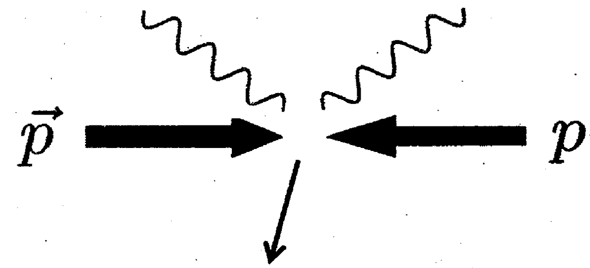


$$\hat{y} = \frac{1}{2}\ln\left(\frac{1+\cos\hat{\theta}}{1-\cos\hat{\theta}}\right)$$

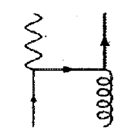


$\sqrt{\hat{s}} = 100$ GeV

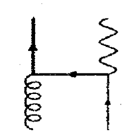
$$A_L = \frac{\Delta s'_1 g_2 \otimes d\Delta\hat{\sigma}_{sg} + \Delta g_1 s'_2 \otimes d\Delta\hat{\sigma}_{gs}}{s'_1 g_2 \otimes d\hat{\sigma}_{sg} + g_1 s'_2 \otimes d\hat{\sigma}_{gs}}$$



- Forward W : $A_L \sim \frac{\Delta s'_1 g_2}{s'_1 g_2} \frac{\Delta\hat{\sigma}_{sg}}{\hat{\sigma}_{sg}} = \frac{\Delta s'_1}{s'_1} \cdot \hat{a}_{sg}$



- Backward W : $A_L \sim \frac{\Delta g_1 s'_2}{g_1 s'_2} \frac{\Delta\hat{\sigma}_{gs}}{\hat{\sigma}_{gs}} = \frac{\Delta g_1}{g_1} \cdot \hat{a}_{gs}$



Spin asymmetry

- Single-spin asymmetry

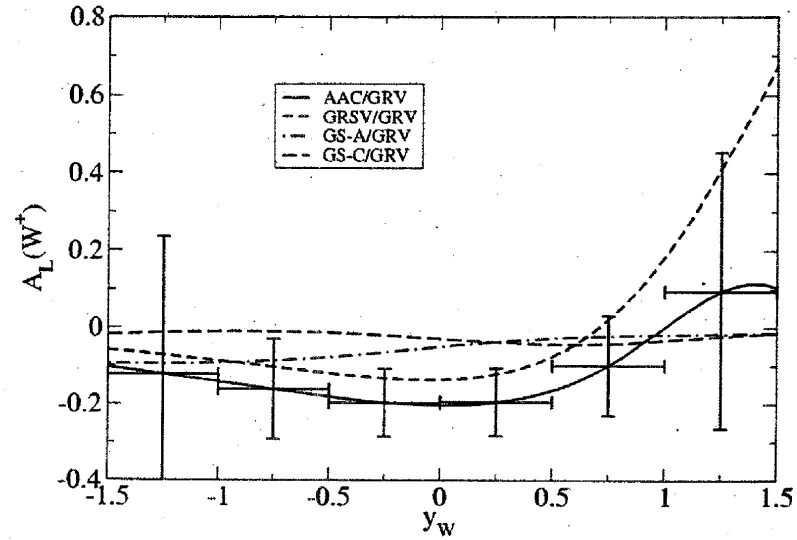
$$A_L(y_W) = \frac{d\Delta\sigma}{dy_W} \Big/ \frac{d\sigma}{dy_W}$$

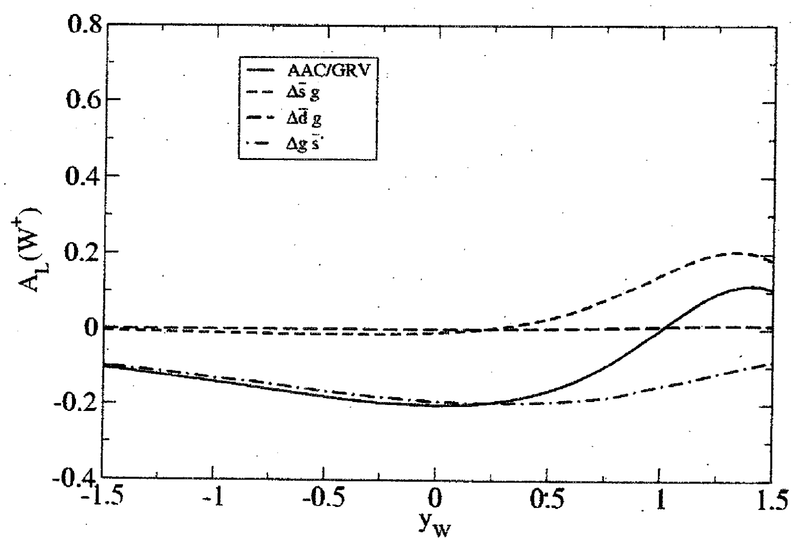
- Expected statistical error

$$\delta A_L = \frac{1}{P}\frac{1}{\sqrt{\sigma \cdot L \cdot \epsilon}}$$

Polarization degree : $P = 0.7$
Luminosity : $L = 800\ \mathrm{pb}^{-1}$
Detection efficiency : $\epsilon = 0.1$

$W^+\bar{c}$





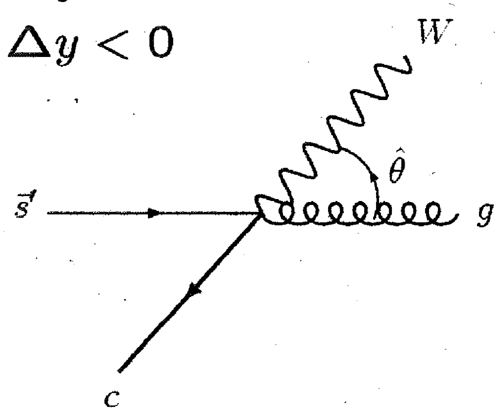
Spin asymmetry

$W^+\bar{c}$

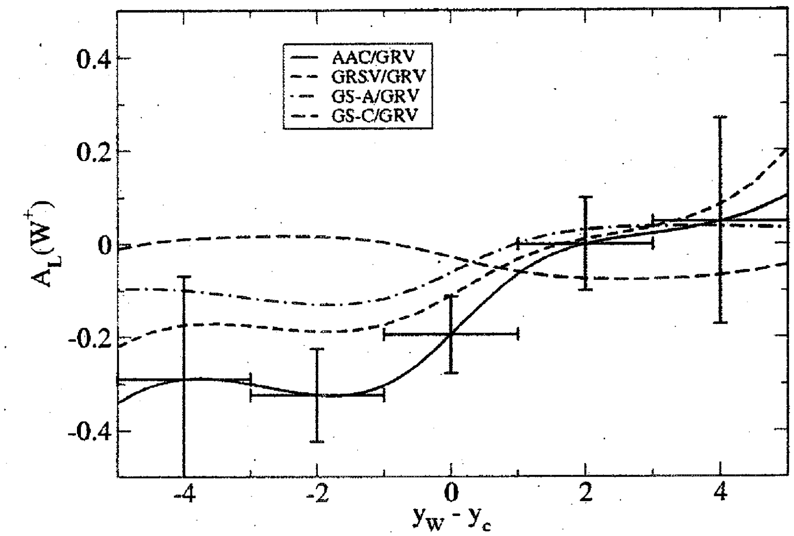
Rapidity difference : $\Delta y = y_W - y_c$

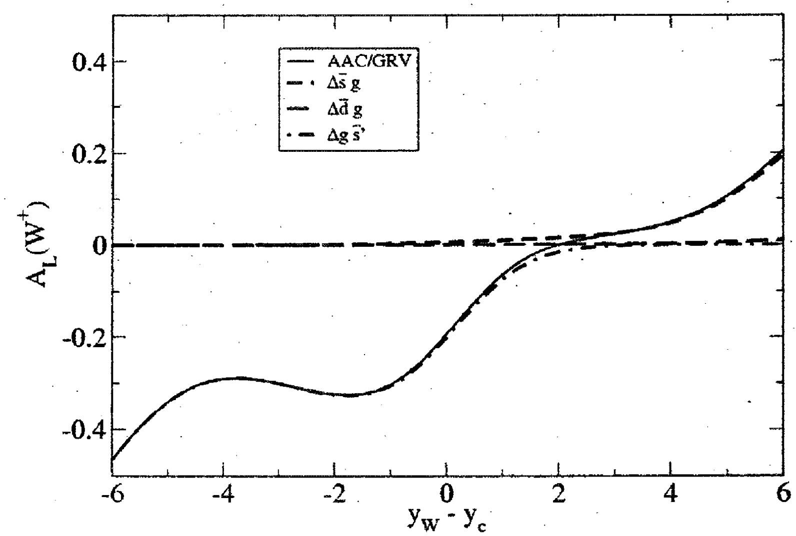
Δy has good correlation
with partonic scattering angle $\hat{\theta}$

$\cos\hat{\theta} > 0 \leftrightarrow \Delta y > 0$
$\cos\hat{\theta} < 0 \leftrightarrow \Delta y < 0$



clear separation of Δs and Δg





Flavor Structure of the Nucleon and W - Production

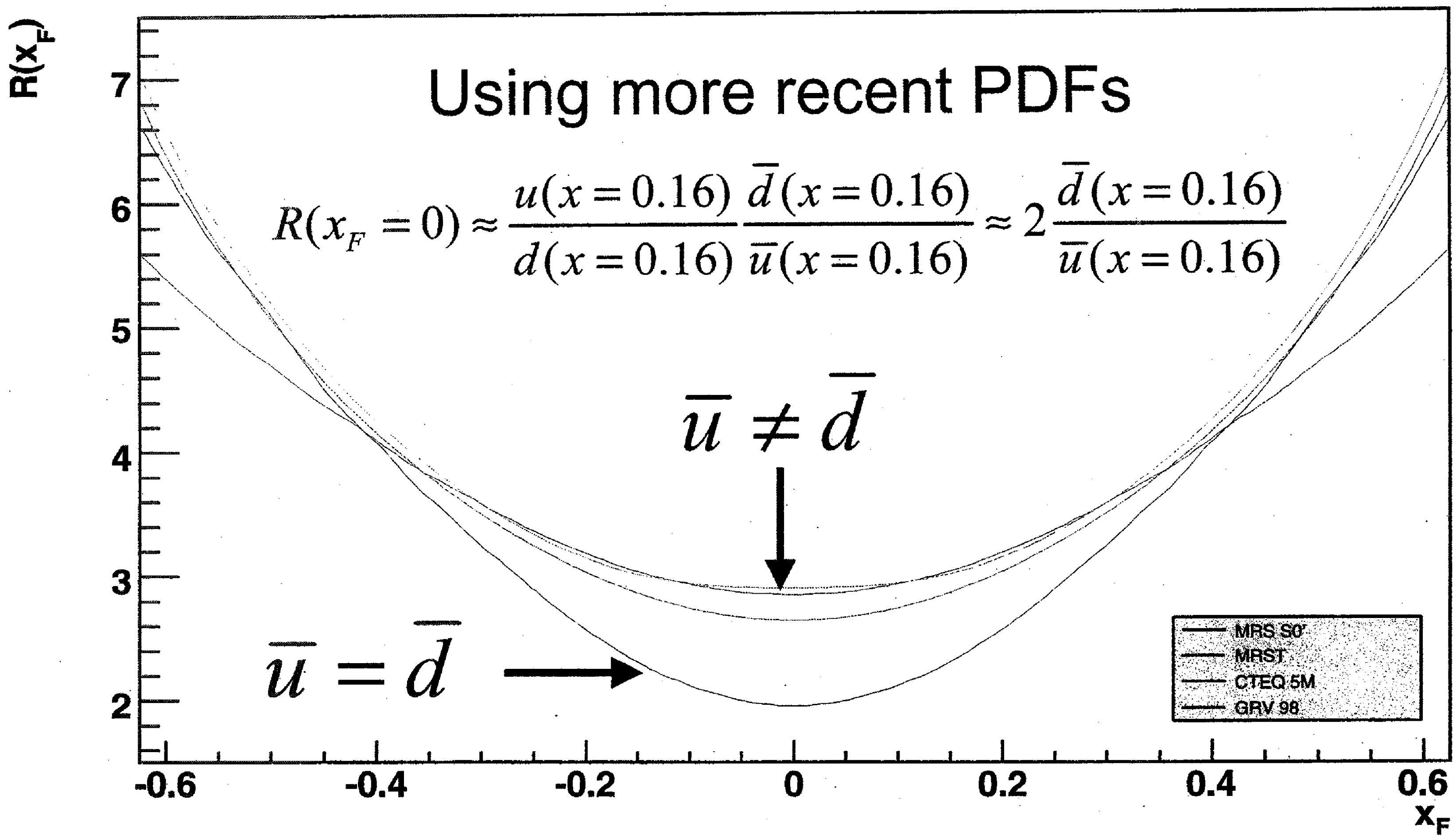
Jen-Chieh Peng
University of Illinois

Workshop on "Parity-Violating Spin Asymmetries at RHIC"
RIKEN-BNL, April 26-27, 2007

- $\bar{d}/\bar{u}$ asymmetry and W-production
- Charge-symmetry violation and W-production
- d/u ratios at large $-x$ and W-production

$\bar{d} / \bar{u}$ from W production at RHIC

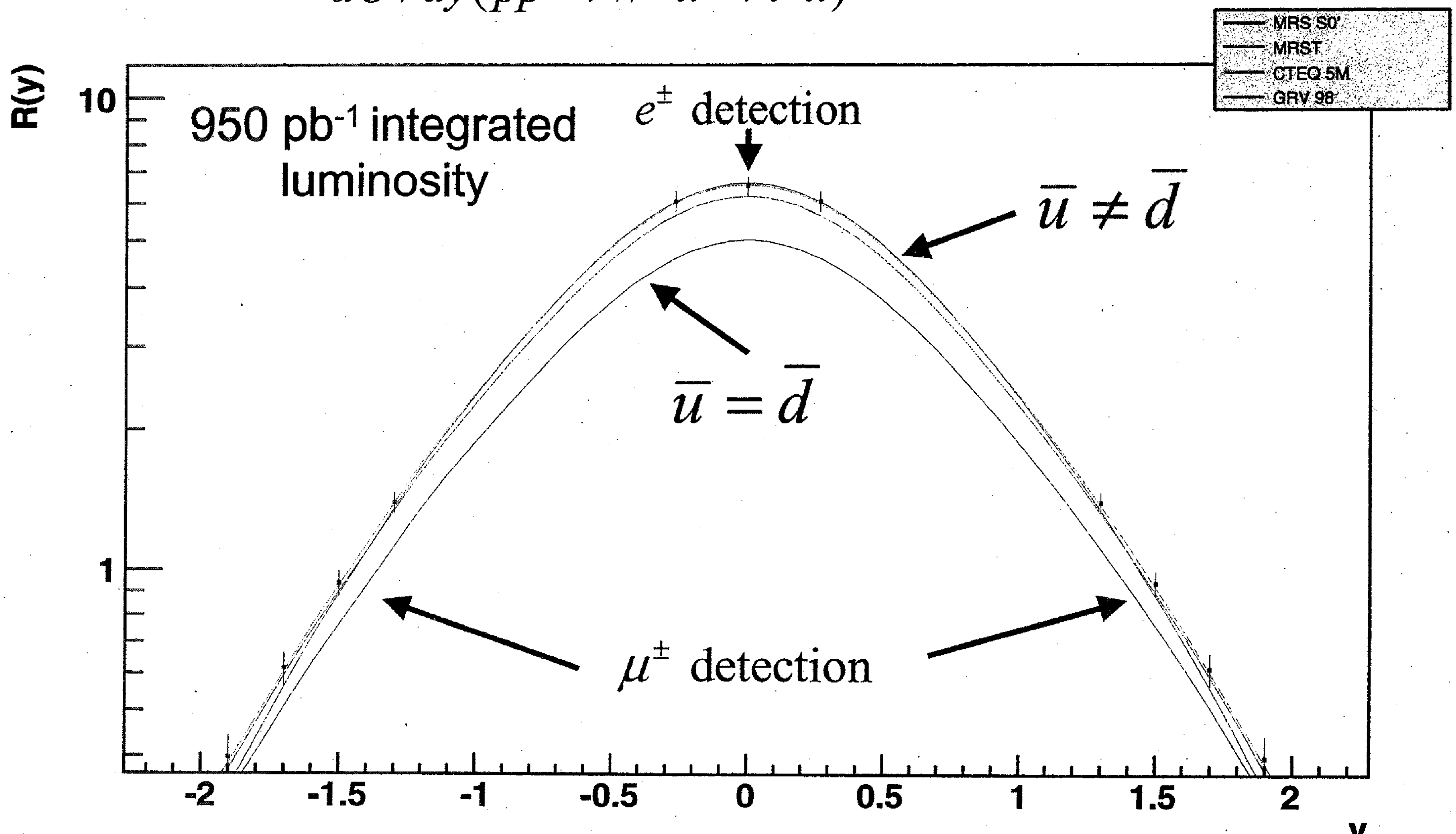
$$R(x_F) = \frac{d\sigma / dx_F (pp \rightarrow W^+ x)}{d\sigma / dx_F (pp \rightarrow W^- x)} \quad \text{at } \sqrt{s} = 500 \text{ GeV}$$



R. Z. Yang and Peng (2007)

$\bar{d} / \bar{u}$ from W production at PHENIX

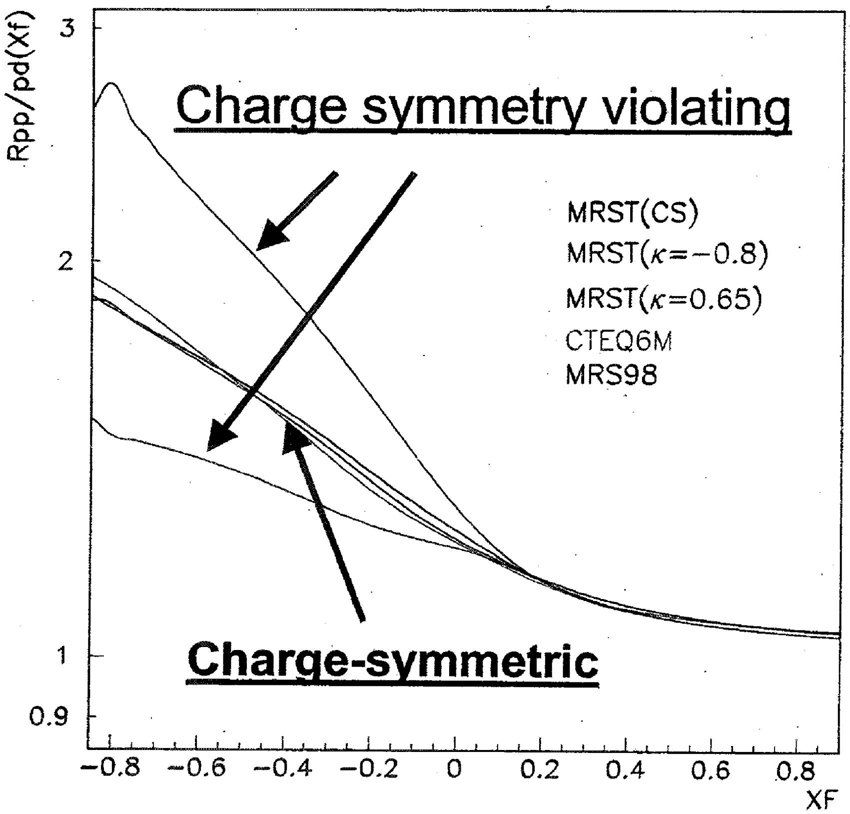
$$R(y) = \frac{d\sigma / dy(pp \to W^+x \to l^+x)}{d\sigma / dy(pp \to W^-x \to l^-x)} \text{ at } \sqrt{s} = 500 \text{ GeV}$$



R. Z. Yang and Peng (2007)

CSV from W production at RHIC

$$R(x_F) = \frac{2d\sigma/dx_F(pp \to W^+x)}{d\sigma/dx_F(pd \to W^+x)} \quad \text{at } \sqrt{s} = 500 \text{ GeV}$$



$$R(x_F) = \frac{d\sigma/dx_F(pd \to W^+x)}{2d\sigma/dx_F(pp \to W^+x)}$$

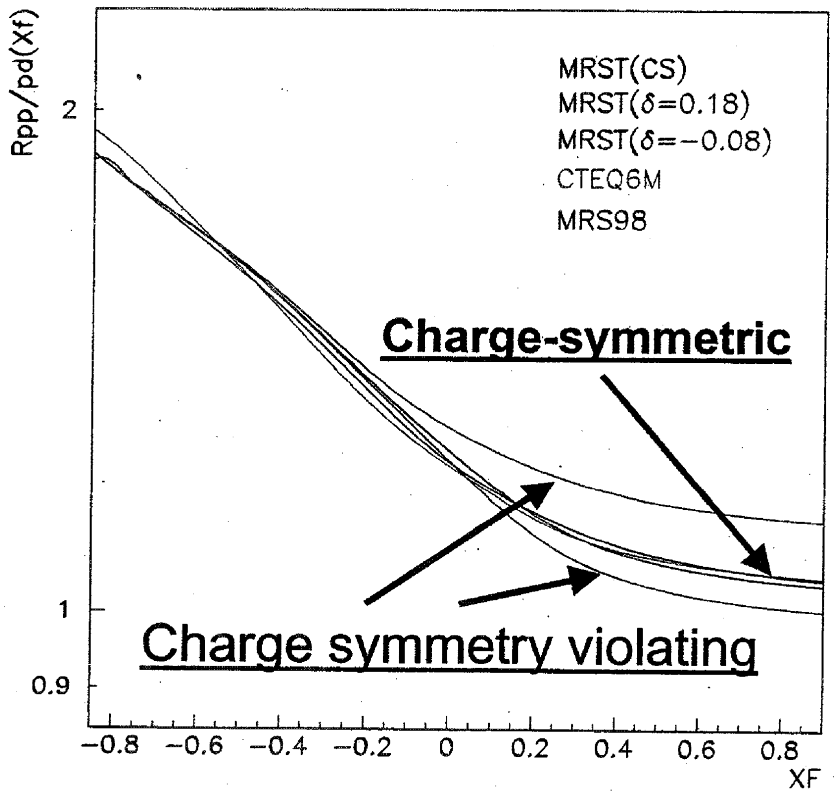
$$\approx \frac{1}{2}\left(1 + \frac{d(x_2)}{u(x_2)} - \frac{\delta d(x_2)}{u(x_2)}\right)$$

for $x_F = 0$, $R(x_F)$ is sensitive to valence-quark CSV

(S. Yoon and Peng, 2006)

CSV from W production at RHIC

$$R(x_F) = \frac{2d\sigma / dx_F(pp \to W^+ x)}{d\sigma / dx_F(pd \to W^+ x)} \quad \text{at } \sqrt{s} = 500 \text{ GeV}$$



$$R(x_F) = \frac{d\sigma / dx_F(pd \to W^+ x)}{2d\sigma / dx_F(pp \to W^+ x)}$$

$$\approx \frac{1}{2}\left(1 + \frac{\bar{d}(x_2)}{\bar{u}(x_2)} - \frac{\delta\bar{d}(x_2)}{\bar{u}(x_2)}\right)$$

for x_F ? 0, $R(x_F)$ is sensitive to sea-quark CSV

(S. Yoon and Peng, 2006)

d/u from W production at RHIC?

$$R(x_F) \equiv \frac{\frac{d\sigma}{dx_F}(pp \to W^+X)}{\frac{d\sigma}{dx_F}(pp \to W^-X)}$$

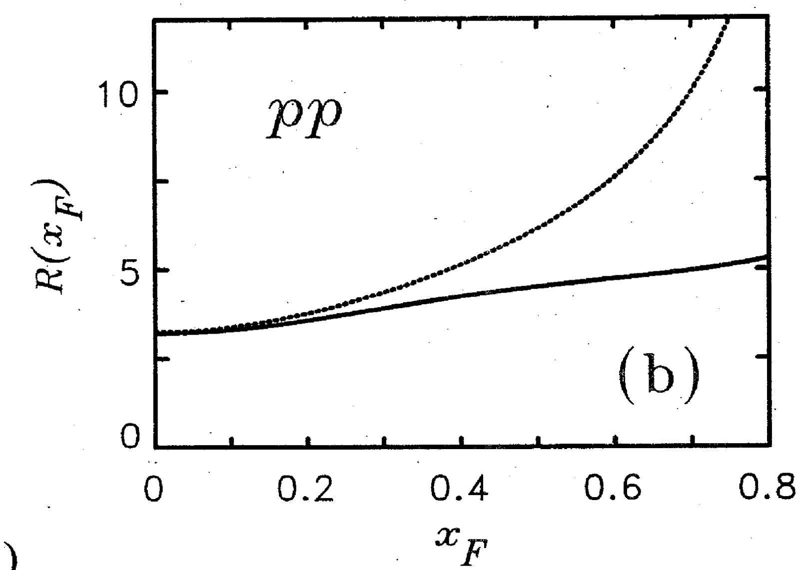
$$; \frac{u(x_1)\bar{d}(x_2)+\bar{d}(x_1)u(x_2)}{\bar{u}(x_1)d(x_2)+d(x_1)\bar{u}(x_2)}$$

$$x_F = x_1 - x_2 \; ; \quad R(x_F) = R(-x_F)$$

At large x_F $(x_1 >> x_2)$, $R(x_F) ; \frac{u(x_1)}{d(x_1)} \frac{\bar{d}(x_2)}{\bar{u}(x_2)}$

At $x_F = 0$ $(x_1 = x_2 = x)$, $R(x_F) = \frac{u(x)}{d(x)} \frac{\bar{d}(x)}{\bar{u}(x)}$

$\sigma(pp \to W^+)/\sigma(pp \to W^-)$ at $\sqrt{s} = 500$ GeV



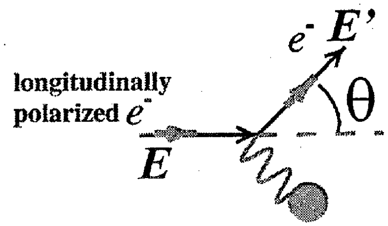
Melnitchouk and Peng
(PL B400 (1997) 220)

Experiments on Parity Violation at JLab

P. A. Souder, Syracuse University

Summary: The program in parity violation at JLab is reviewed. There are four main physics topics; 1) Measurements of electroweak form factors, 2) tests of the Standard Model, 3) measurement of the radius of the neutron distribution in Pb, and 4) measurements of properties of deep inelastic scattering beyond the parton model. A significant number of results have already been published that demonstrate that the measurement of small parity-violating asymmetries is a practical tool for studying both fundamental interactions and also hadron structure.

Parity-Violating Electron Scattering



4-momentum transfer

$$Q^2 = 4EE'\sin^2\frac{\theta}{2}$$

$$\sigma \;\alpha\; |A_{EM} + A_{weak}|^2$$

$$\sim |A_{EM}|^2 + \boxed{2A_{EM}A^*_{weak}} + \ldots$$

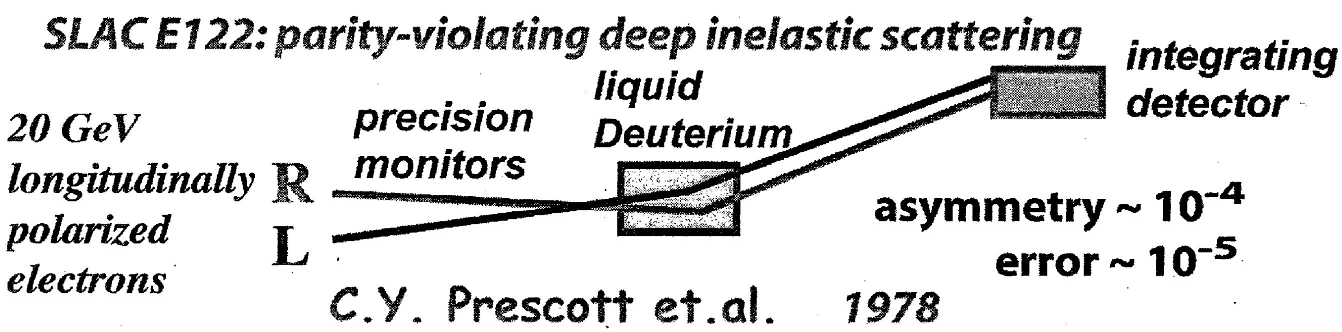
Parity-violating

$$A_{PV} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} \sim \frac{A_{weak}}{A_{EM}} \sim \frac{G_F Q^2}{4\pi\alpha}$$

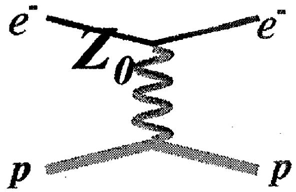
$$A_{PV} \sim 10^{-4} \cdot Q^2 \text{ (GeV}^2)$$

It was realized independently in the mid 70s at SLAC:

A_{PV} in Deep Inelastic Scattering off liquid Deuterium: $Q^2 \sim 1$ (GeV)^2



Elastic Electroweak Scattering



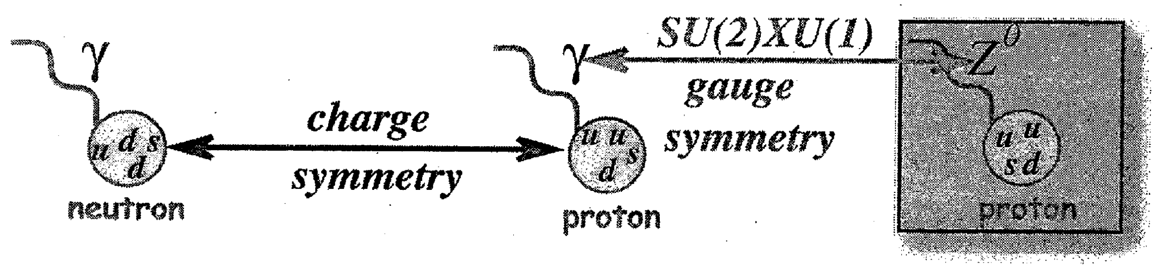
A_{PV} for elastic e-p scattering:

$$A = \left[\frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\right]\frac{A_E + A_M + A_A}{\sigma_p}$$

$$A_E = \varepsilon G_E^p G_E^Z, \quad A_M = \tau G_M^p G_M^Z, \quad A_A = -\left(1 - 4\sin^2\theta_W\right)\varepsilon G_M^p G_A^e$$

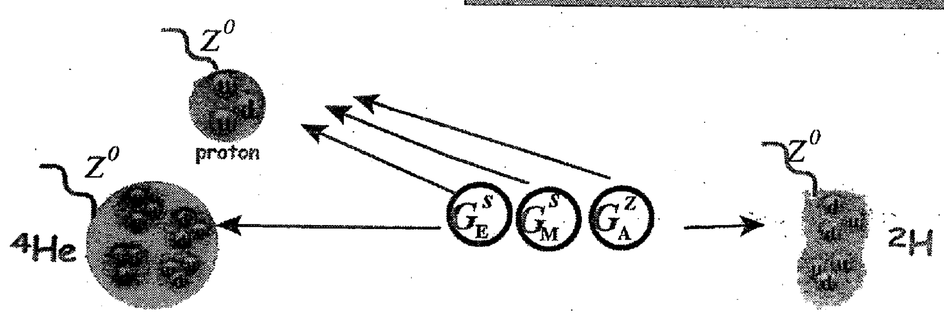
Forward angle — Backward angle

Kaplan & Manohar (1988)
McKeown (1989)



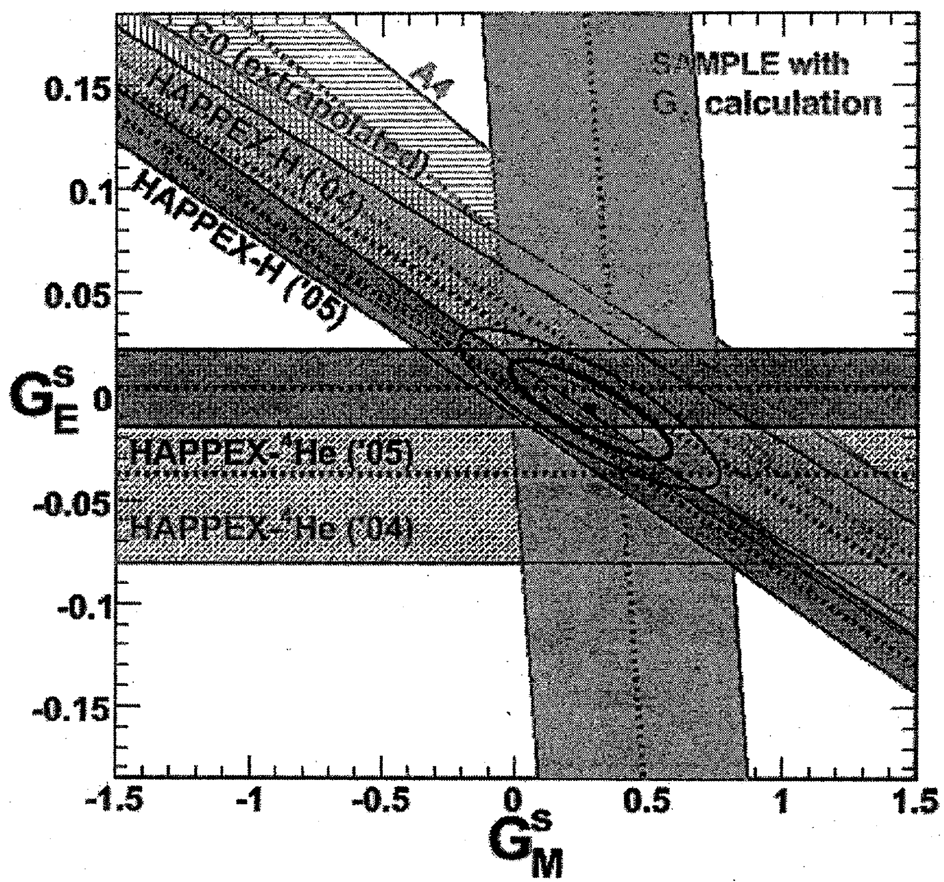
$$G_p^Z \sim (1 - 4\sin^2\theta_W)\, G_p^\gamma - G_n^\gamma - G_s$$

$\Rightarrow$ $G_E^s(Q^2)$, $G_M^s(Q^2)$



Helium: Unique G_E sensitivity
Deuterium: Enhanced G_A sensitivity

Five Experiments are Consistent



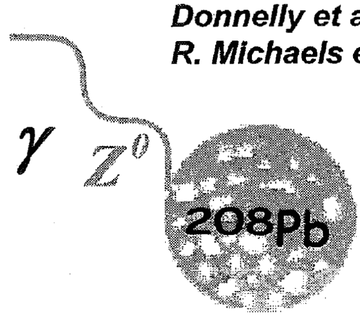
PREx at Jefferson Lab

$\delta(A_{PV}) \sim 3\%$ ⇒ $\delta(R_p - R_n) \sim 1\%$ $Q^2 \sim 0.01\ GeV^2$ ⇒ $A_{PV} \sim 0.5$ ppm

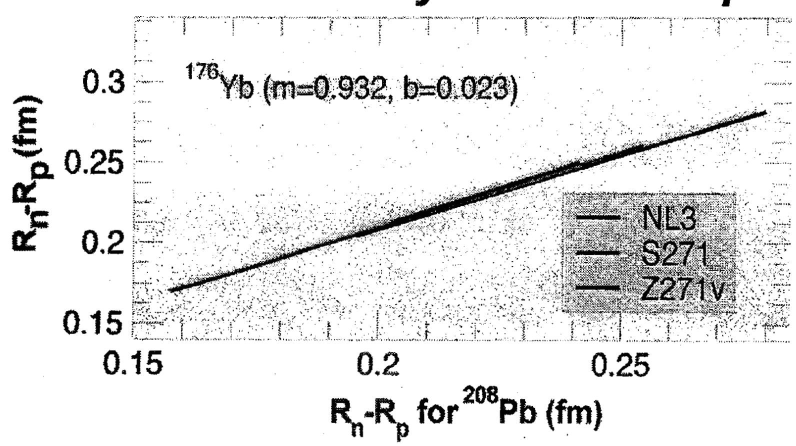
$Q^p_{EM} \sim 1$ $Q^n_{EM} \sim 0$

$Q^n_W \sim 1$ $Q^p_W \sim 1 - 4\sin^2\theta_W$

Donnelly et al, 1988
R. Michaels et al, 2001



Constrain neutron skin for Atomic Parity Violation Expts



A technically demanding measurement:

- Rate ~ 2 GHz
- Separate excited state at 2.6 MeV
- Stat. Error ~ 15 ppb
- Syst. Error ~ 1 to 2 %

Tentatively scheduled to run in 2008

- *Tight control of beam properties*
- *New "warm" septum*
- *High power Lead target*
- *New 18-bit ADC*
- *New radiation-hard detector*
- *Polarimetry upgrade*

Opportunity with JLab @ 12 GeV

Moderately high beam energy:
Consider Møller scattering

Very Large Polarized Luminosity

$I_{beam} = 90\ \mu A$

150 cm LH_2 target

E': 3-6 GeV

θ_{lab} = 0.53°-0.92°

A_{PV} = 40 ppb

4000 hours

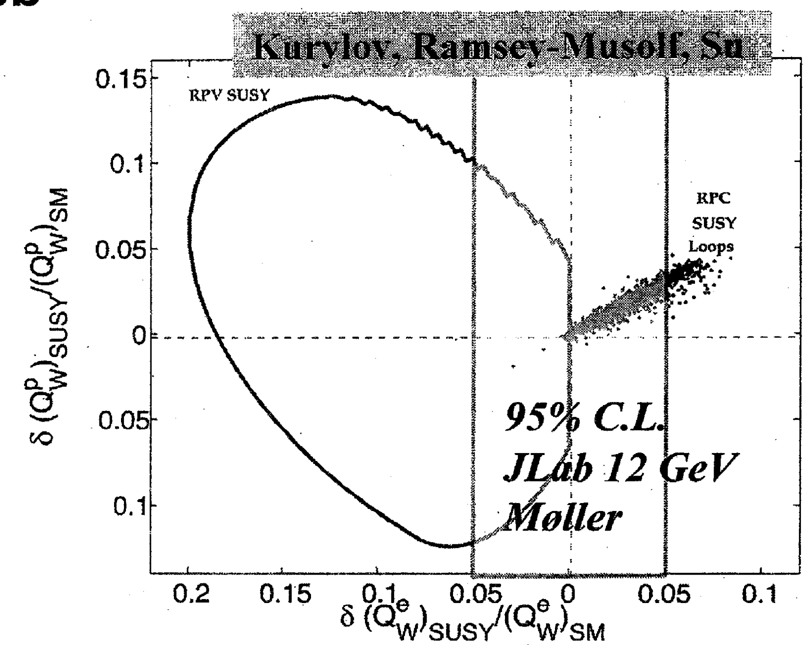
$\delta(A_{PV})$=0.58 ppb

Very challenging experiment: would be worth the payoff

$\sin^2\theta_W$ to ± 0.00025!
Λ_{ee} ~ 25 TeV reach!

e.g. Z' reach ~ 2.5 TeV

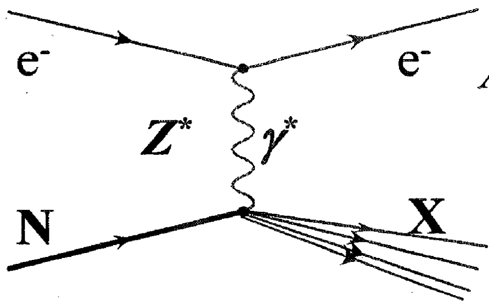
- *shed light on Z-pole asymmetry discrepancy*
- *Best new measurement until ILC or ν-Factory*
- *Could be launched ~ 2013*



Does Supersymmetry (SUSY) provide a candidate for dark matter?

- **Neutralino is stable if baryon (B) and lepton (L) numbers are conserved**
- **B and L need not be conserved (RPV): neutralino decay**

PV DIS at 11 GeV with LD_2



$$A_{PV} = \frac{G_F Q^2}{\sqrt{2}\pi\alpha}\left[a(x) + f(y)b(x)\right]$$

$$y \equiv 1 - E'/E$$

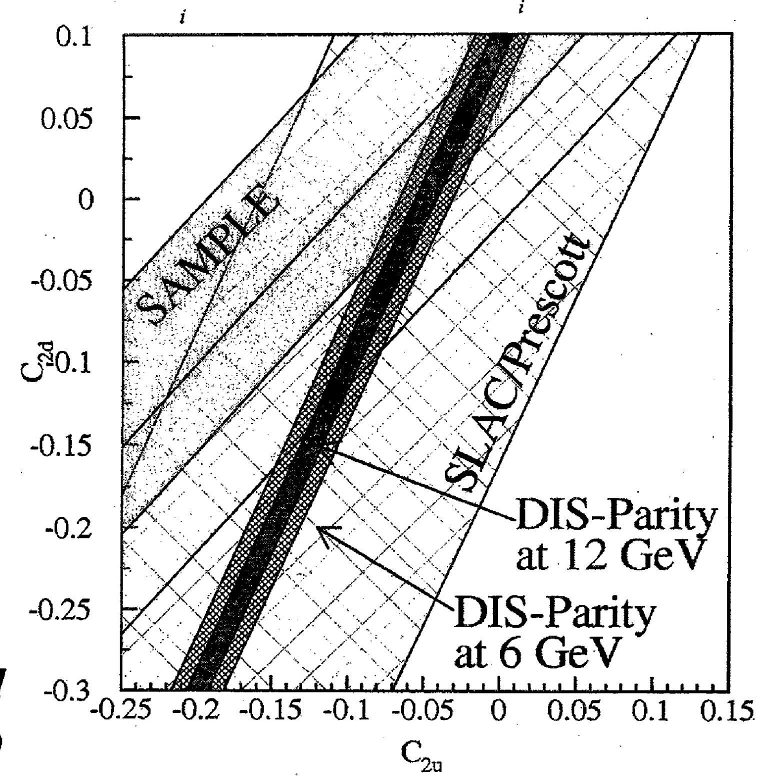
$$a(x) = \frac{\sum_i C_{1i} Q_i f_i(x)}{\sum_i Q_i^2 f_i(x)} \qquad b(x) = \frac{\sum_i C_{2i} Q_i f_i(x)}{\sum_i Q_i^2 f_i(x)}$$

For an isoscalar target like ^2H, structure functions largely cancel in the ratio:

$$a(x) = \frac{3}{10}\left[(2C_{1u} - C_{1d})\right] + \cdots$$

$$b(x) = \frac{3}{10}\left[(2C_{2u} - C_{2d})\frac{u_v(x) + d_v(x)}{u(x) + d(x)}\right] + \cdots$$

($Q^2 >> 1$ GeV^2 , $W^2 >> 4$ GeV^2, $x \sim 0.3$-0.5)



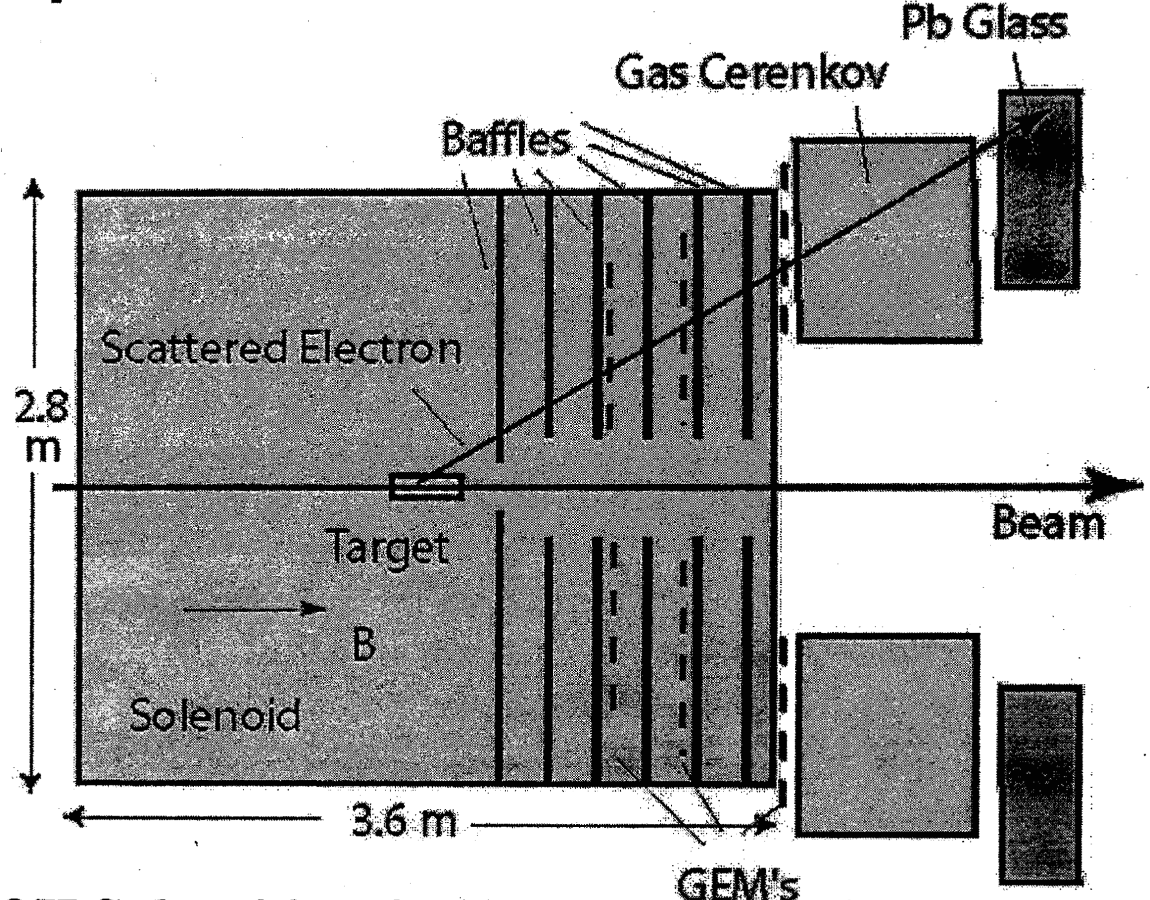
- ***Must measure A_{PV} to 0.5% fractional accuracy!***
- ***Luminosity and beam quality available at JLab***

- **Important constraint for potential Large Hadron Collider anomalies**
- **However, extraction of C_{2i}'s assumes nucleon with valence quarks**
- **Need to characterize nucleon structure at high-x to high precision**
- **This is one of the core missions of the 11 GeV Jlab program!**

Large Acceptance Solenoid

Solenoid takes advantage of the small beam spot requires less bending

With solenoid, detectors can be far from target. Small beam spot gives excellent resolution



- *Need BaBar, CDF or CLEOII Solenoid: refurbishing ~ 1-2 M$*
- *Total cost ~ 10M$; diverse physics topics addressed:*
  - *Standard Model test, CSV, d/u, nuclear EMC effect, semi-inclusive physics, detailed studies of spin structure functions…*

Parity-Violating Spin Asymmetries at RHIC

A RIKEN BNL Research Center Workshop

April 26 – 27, 2007

List of Registered Participants

Name and Affiliation	E-Mail Address
Christine Aidala, Univ. of Massachusetts/Amherst	caidala@bnl.gov
Leandro Almeida, Stony Brook University	lalmeida@quark.phy.bnl.gov
Simone Arnold, Ruhr-Universitaet Bochum	simone.menzel@rub.de
Mei Bai, BNL	mbai@bnl.gov
Kenneth Barish, UC Riverside	kenneth.barish@ucr.edu
Gerry Bunce, RBRC and BNL	bunce@bnl.gov
Kieran Boyle, Stony Brook University	kboyle@grad.physics.sunysb.edu
Jian-Ping Chen, Jefferson Lab	jpchen@jlab.org
Mickey Chiu, BNL	chiu@bnl.gov
William Christie, BNL	christie@bnl.gov
Abhay Deshpande, Stony Brook University	abhay@bnl.gov
Frank Ellinghaus, University of Colorado and BNL	frank.ellinghaus@desy.de
Michael Finger, Charles University - Prague	michael.finger@cern.ch
Miroslav Finger, Charles University - Prague	miroslav.finger@cern.ch
Yuji Goto, RIKEN / RBRC	goto@bnl.gov
Wlodek Guryn, BNL	guryn@bnl.gov
George Igo, UCLA	igo@physics.ucla.edu
Xiadong Jiang, Jefferson Lab	jiang@jlab.org
Edward Kinney, University of Colorado	edward.kinney@colorado.edu
J. H. Lee, BNL	jhlee@bnl.gov
Ming Liu, Los Alamos National Lab	mliu@lanl.gov
Waldo MacKay, BNL	waldo@bnl.gov
Andreas Metz, Ruhr-Universitaet Bochum	andreas.metz@tp2.ruhr-uni-bochum.de
Asmita Mukherjee, IT Bombay	asmita@phy.iitb.ac.in
Pavel Nadolsky, Argonne National Laboratory	nadolsky@hep.anl.gov
Itaru Nakagawa, RIKEN, RBRC	itaru@bnl.gov
Kensuke Okada, BNL	okada@bnl.gov
Shigemi Ohta, IPNS/KEK and RBRC	shigemiohta@mac.com
Jen-Chieh Peng, Univ. of Illinois, Urbana-Champaign	jcpeng@uiuc.edu
Matthias Perdekamp, Univ. of Illinois, Urbana-Champaign	mperdekamp@gmail.com
Michael Rijssenbeek, SUNY Stony Brook	michael.rijssenbeek@stonybrook.edu
Vladimir Rykov, Kent State University	rykov@bnl.gov
Helena Santos, LIP	helena@lip.pt
Ralf Seidl, Univ. of Illinois, Urbana-Champaign	rseidl@uiuc.edu
Ernst Sichtermann, Lawrence Berkeley Lab	EPSichtermann@lbl.gov
Frank Simon, MIT	fsimon@mit.edu

Parity-Violating Spin Asymmetries at RHIC

A RIKEN BNL Research Center Workshop

April 26 – 27, 2007

List of Registered Participants

Name and Affiliation	E-Mail Address
Jacques Soffer, MISP	jacques.soffer@Gmail.com
Paul Souder, Syracuse University	souder@physics.syr.edu
James Sowinski, Indiana University	sowinski@indiana.edu
Marco Stratmann, RIKEN	marco@ribf.riken.jp
Bernd Surrow, MIT	surrow@mit.edu
Michael Tannenbaum, BNL	mgt@bnl.gov
Larry Trueman, BNL	trueman@bnl.gov
Werner Vogelsang, BNL Nuclear Theory	vogelsan@bnl.gov
Christian Weiss, Jefferson Lab	weiss@jlab.org
Wei Xie, RBRC	xiewei@rcf2.rhic.bnl.gov
Hiroshi Yokoya, Niigata University	yokoya@nt.sc.niigata-u.ac.jp
Feng Yuan, RBRC	fyuan@quark.phy.bnl.gov

AGENDA

Parity-Violating Spin Asymmetries at RHIC
A RIKEN BNL Research Center Workshop
April 26 – 27, 2007

(Physics Department Large Seminar Room)

Thursday Morning, April 26, 2007
Motivation for W physics at RHIC (Chair: L. Trueman)

08:30- 09:00		***REGISTRATION AND COFFEE***
09:00- 09:05	N. Samios	**WELCOME**
09:05 – 09:50	J. Soffer	*Opening talk*: Spin and W physics
09:50 – 10:35	C. Weiss	Models for the polarized nucleon sea
10:35 – 11:00		**COFFEE**
11:00 – 11:30	M. Bai	Polarized protons in RHIC at 500 GeV
11:30 – 12:15	P. Nadolsky	RHICBOS studies
12:15 – 12:45	S. Arnold	Studies of hadronic W decays at RHIC
12:45 – 2:00		**LUNCH**

Thursday Afternoon, April 26, 2007
Determinations of polarized sea distributions in SIDIS (Chair: G. Bunce)

2:00 – 2:30	J.P. Chen	Quark Polarizations from SIDIS at JLab
2:30 – 3:00	H. Santos	Inclusive and SIDIS at COMPASS
3:00 – 3:30	M. Stratmann	Fragmentation functions and SIDIS
3:30 – 4:00		**COFFEE**
4:00 – 4:30	E. Kinney	SIDIS at HERMES
4:30 – 5:00	X. Jiang	Future SIDIS studies at Jlab
5:00	**DISCUSSION**	SIDIS

Parity-Violating Spin Asymmetries at RHIC

Friday Morning, April 27, 2007
W physics experiments at RHIC (Chairs: M. Perdekamp / B. Surrow)

9:00 – 9:45	R. Seidl	Plans and prospects for W-physics with PHENIX
9:45 – 10:30	F. Simon	Plans and prospects for W-physics with STAR
10:30 – 11:00		**COFFEE**
11:00 – 11:30	M. Rijssenbeek	W reconstruction at the Tevatron and SPS
11:30 – 12:30	**DISCUSSION**	RHIC detector capabilities
12:30 – 2:00		**LUNCH**

Friday Afternoon, April 27, 2007
Theory studies and other opportunities in W physics (Chair: W. Vogelsang)

2:00 – 2:30	A. Mukherjee	Threshold resummation for W production at RHIC
2:30 – 3:00	H. Yokoya	Future possibilities for W physics
3:00 – 3:30	**DISCUSSION**	Tasks for theory and impact of RHIC W data on global pdf analysis
3:30 – 4:00		**COFFEE**
4:00 – 4:30	J. C. Peng	Flavor structure of the nucleon and W-production
4:30 – 5:00	P. Souder	Experiments on Parity Violation at JLab

Additional RIKEN BNL Research Center Proceedings:

Volume 85 – Parity-Violating Spin Asymmetries at RHIC – BNL-
Volume 84 – Domain Wall Fermions at Ten Years – BNL-77857-2007
Volume 83 – QCD in Extreme Conditions, July 31-August 2, 2006 – BNL 76933-2006
Volume 82 – RHIC Physics in the Context of the Standard Model, June 18-23, 2006 – BNL-76863-2006
Volume 81 – Parton Orbital Angular Momentum (Joint RBRC/University of New Mexico Workshop) February 24-26, 2006 – BNL-
Volume 80 – Can We Discover the QCD Critical Point at RHIC? BNL-75692-2006
Volume 79 – Strangeness in Collisions, February 16-17, 2006 – BNL-
Volume 78 – Heavy Flavor Productions and Hot/Dense Quark Matter, December 12-14, 2005 – BNL-
Volume 77 – RBRC Scientific Review Committee Meeting – BNL-52649
Volume 76 – Odderon Searches at RHIC, September 27-29, 2005 – BNL-75092-2005
Volume 75 – Single Spin Asymmetries, June 1-3, 2005 – BNL-74717-2005
Volume 74 – RBRC QCDOC Computer Dedication and Symposium on RBRC QCDOC, May 26, 2005 – BNL-74813-2005
Volume 73 – Jet Correlations at RHIC, March 10-11, 2005 – BNL-73910-2005
Volume 72 – RHIC Spin Collaboration Meetings XXXI(January 14, 2005), XXXII (February 10, 2005), XXXIII (March 11, 2005) – BNL-73866-2005
Volume 71 – Classical and Quantum Aspects of the Color Glass Condensate – BNL-73793-2005
Volume 70 – Strongly Coupled Plasmas: Electromagnetic, Nuclear & Atomic – BNL-73867-2005
Volume 69 – Review Committee – BNL-73546-2004
Volume 68 – Workshop on the Physics Programme of the RBRC and UKQCD QCDOC Machines – BNL-73604-2004
Volume 67 – High Performance Computing with BlueGene/L and QCDOC Architectures – BNL-
Volume 66 – RHIC Spin Collaboration Meeting XXIX, October 8-9, 2004, Torino Italy – BNL-73534-2004
Volume 65 – RHIC Spin Collaboration Meetings XXVII (July 22, 2004), XXVIII (September 2, 2004), XXX (December 6, 2004) - BNL-73506-2004
Volume 64 – Theory Summer Program on RHIC Physics – BNL-73263-2004
Volume 63 – RHIC Spin Collaboration Meetings XXIV (May 21, 2004), XXV (May 27, 2004), XXVI (June 1, 2004) – BNL-72397-2004
Volume 62 – New Discoveries at RHIC, May 14-15, 2004 – BNL- 72391-2004
Volume 61 – RIKEN-TODAI Mini Workshop on "Topics in Hadron Physics at RHIC", March 23-24, 2004 – BNL-72336-2004
Volume 60 – Lattice QCD at Finite Temperature and Density – BNL–72083-2004
Volume 59 – RHIC Spin Collaboration Meeting XXI (January 22, 2004), XXII (February 27, 2004), XXIII (March 19, 2004)– BNL-72382-2004
Volume 58 – RHIC Spin Collaboration Meeting XX – BNL-71900-2004
Volume 57 – High pt Physics at RHIC, December 2-6, 2003 – BNL-72069-2004
Volume 56 – RBRC Scientific Review Committee Meeting – BNL-71899-2003
Volume 55 – Collective Flow and QGP Properties – BNL-71898-2003

Additional RIKEN BNL Research Center Proceedings:

Volume 54 – RHIC Spin Collaboration Meetings XVII, XVIII, XIX – BNL-71751-2003
Volume 53 – Theory Studies for Polarized *pp* Scattering – BNL-71747-2003
Volume 52 – RIKEN School on QCD "Topics on the Proton" – BNL-71694-2003
Volume 51 – RHIC Spin Collaboration Meetings XV, XVI – BNL-71539-2003
Volume 50 – High Performance Computing with QCDOC and BlueGene – BNL-71147-2003
Volume 49 – RBRC Scientific Review Committee Meeting – BNL-52679
Volume 48 – RHIC Spin Collaboration Meeting XIV – BNL-71300-2003
Volume 47 – RHIC Spin Collaboration Meetings XII, XIII – BNL-71118-2003
Volume 46 – Large-Scale Computations in Nuclear Physics using the QCDOC – BNL-52678
Volume 45 – Summer Program: Current and Future Directions at RHIC – BNL-71035
Volume 44 – RHIC Spin Collaboration Meetings VIII, IX, X, XI – BNL-71117-2003
Volume 43 – RIKEN Winter School – Quark-Gluon Structure of the Nucleon and QCD – BNL-52672
Volume 42 – Baryon Dynamics at RHIC – BNL-52669
Volume 41 – Hadron Structure from Lattice QCD – BNL-52674
Volume 40 – Theory Studies for RHIC-Spin – BNL-52662
Volume 39 – RHIC Spin Collaboration Meeting VII – BNL-52659
Volume 38 – RBRC Scientific Review Committee Meeting – BNL-52649
Volume 37 – RHIC Spin Collaboration Meeting VI (Part 2) – BNL-52660
Volume 36 – RHIC Spin Collaboration Meeting VI – BNL-52642
Volume 35 – RIKEN Winter School – Quarks, Hadrons and Nuclei – QCD Hard Processes and the Nucleon Spin – BNL-52643
Volume 34 – High Energy QCD: Beyond the Pomeron – BNL-52641
Volume 33 – Spin Physics at RHIC in Year-1 and Beyond – BNL-52635
Volume 32 – RHIC Spin Physics V – BNL-52628
Volume 31 – RHIC Spin Physics III & IV Polarized Partons at High Q^2 Region – BNL-52617
Volume 30 – RBRC Scientific Review Committee Meeting – BNL-52603
Volume 29 – Future Transversity Measurements – BNL-52612
Volume 28 – Equilibrium & Non-Equilibrium Aspects of Hot, Dense QCD – BNL-52613
Volume 27 – Predictions and Uncertainties for RHIC Spin Physics & Event Generator for RHIC Spin Physics III – Towards Precision Spin Physics at RHIC – BNL-52596
Volume 26 – Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics – BNL-52588
Volume 25 – RHIC Spin – BNL-52581
Volume 24 – Physics Society of Japan Biannual Meeting Symposium on QCD Physics at RIKEN BNL Research Center – BNL-52578
Volume 23 – Coulomb and Pion-Asymmetry Polarimetry and Hadronic Spin Dependence at RHIC Energies – BNL-52589
Volume 22 – OSCAR II: Predictions for RHIC – BNL-52591
Volume 21 – RBRC Scientific Review Committee Meeting – BNL-52568
Volume 20 – Gauge-Invariant Variables in Gauge Theories – BNL-52590

Additional RIKEN BNL Research Center Proceedings:

Volume 19 – Numerical Algorithms at Non-Zero Chemical Potential – BNL-52573
Volume 18 – Event Generator for RHIC Spin Physics – BNL-52571
Volume 17 – Hard Parton Physics in High-Energy Nuclear Collisions – BNL-52574
Volume 16 – RIKEN Winter School - Structure of Hadrons - Introduction to QCD Hard Processes – BNL-52569
Volume 15 – QCD Phase Transitions – BNL-52561
Volume 14 – Quantum Fields In and Out of Equilibrium – BNL-52560
Volume 13 – Physics of the 1 Teraflop RIKEN-BNL-Columbia QCD Project First Anniversary Celebration – BNL-66299
Volume 12 – Quarkonium Production in Relativistic Nuclear Collisions – BNL-52559
Volume 11 – Event Generator for RHIC Spin Physics – BNL-66116
Volume 10 – Physics of Polarimetry at RHIC – BNL-65926
Volume 9 – High Density Matter in AGS, SPS and RHIC Collisions – BNL-65762
Volume 8 – Fermion Frontiers in Vector Lattice Gauge Theories – BNL-65634
Volume 7 – RHIC Spin Physics – BNL-65615
Volume 6 – Quarks and Gluons in the Nucleon – BNL-65234
Volume 5 – Color Superconductivity, Instantons and Parity (Non?)-Conservation at High Baryon Density – BNL-65105
Volume 4 – Inauguration Ceremony, September 22 and Non -Equilibrium Many Body Dynamics –BNL-64912
Volume 3 – Hadron Spin-Flip at RHIC Energies – BNL-64724
Volume 2 – Perturbative QCD as a Probe of Hadron Structure – BNL-64723
Volume 1 – Open Standards for Cascade Models for RHIC – BNL-64722

For information please contact:

Ms. Jane Lysik
RIKEN BNL Research Center
Building 510A
Brookhaven National Laboratory
Upton, NY 11973-5000 USA

Phone: (631) 344-5864
Fax: (631) 344-2562
E-Mail: lysik@bnl.gov

Homepage: http://www.bnl.gov/riken

RIKEN BNL RESEARCH CENTER

Parity-Violating Spin Asymmetries at RHIC

April 26 – 27, 2007

Li Keran

Nuclei as heavy as bulls
Through collision
Generate new states of matter.
T.D. Lee

Speakers:

S. Arnold	E. Kinney	M. Rijssenbeek	J. Soffer
M. Bai A. Mukherjee	H. Santos	P. Souder	M. Stratmann
J.P. Chen	P. Nadolsky	R. Seidl	H. Yokoya
X. Jiang	J.C. Peng	F. Simon	

Organizers: Matthias Perdekamp, Bernd Surrow And Werner Vogelsang