LOOKING INTO THE FUTURE OF SPIN AND QCD

SPIN IS A WONDERFUL TOOL WHICH WILL CONTINUE TO PLAY A CRUCIAL ROLE (AS IN THE PAST)

- TO IMPROVE AND COMPLETE OUR PRESENT KNOWLEDGE ON HADRON DYNAMICS e.g. TEST THE SPIN SECTOR OF QCD

- TO UNCOVER NEW PHYSICS WHICH MIGHT BE AT THE TeV SCALE

INDIRECT CAN REMAIN AT LOW (OR VERY LOW) ENERGY AND USE VERY HIGH PRECISION ON SPECIFIC OBSERVABLES

DIRECT
- USE HIGH ENERGY POL. p BEAMS AT RHIC
- IF YOU DON'T HAVE POL. p, BUILT THE LHC !!
- DON'T FORGET POL. e^+e^- IN LINEAR COLLIDERS

I APOLOGIZE FOR ALL THE TOPICS I WILL HAVE TO LEAVE OUT, EITHER BECAUSE OF MY IGNORANCE OR BY LACK OF TIME.

I never think about the *FUTURE*,

it comes too soon

A. Einstein

To make predictions is very difficult,

mainly when it concerns the *FUTURE*

A.Einstein

Institute for the Future

Future success depends on making the right strategic decisions today.

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SPIN

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Company futures

FUTURE: That period of time in which our affairs prosper, our friends are true, and our happiness is assured. Ambrose Bierce

---

Swami Gondwanawurka's prediction generator

MY TEACHER TO READ OFF THE CRISTAL BOWL

NEUTRON ELECTRIC DIPOLE MOMENT

(R.E. MISCHKE)

IN THE STANDARD MODEL, CP-VIOLATION IN CKM

$d_n < 10^{-31}$ e cm

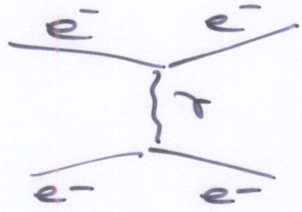
MODELS BEYOND THE SM GIVE LIMITS SEVERAL ORDERS OF MAGNITUDE LARGER

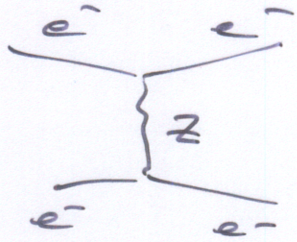
JUST AT THE PRESENT EXPERIMENTAL LIMIT $d_n < 10^{-25}$ (ILL, PSI, LANL)

A NEW EXPERIMENT AT LANL SHOULD PUSH THE LIMIT TO 10^{-27} IN 2 YEARS AND 10^{-28} IN 10 YEARS !!

PARITY VIOLATING ASYMMETRIES

FOR EXAMPLE MØLLER SCATTERING AT SLAC E158





$$A_{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \sim \left(\frac{1}{4} - \sin^2\theta_W \right)$$

$\sin^2\theta_W$ is ACCURATELY KNOWN AT THE Z POLE AND IT IS RUNNING ACCORDING TO THE SM AT LOWER ENERGIES

GOAL $\delta \sin^2\theta_W = \pm 0.0008$ (END OF 2003)

SENSITIVITY TO NEW PHYSICS

COMPOSITENESS $\Lambda = 15$ TeV

NEW BOSON Z' $M_{Z'} = 1$ TeV

LEPTON FLAVOR VIOLATION

THE ANOMALOUS MAGNETIC MOMENT OF THE MUON (E. SICHTERMANN)

$$\vec{\mu} = g \frac{e}{2mc} \vec{s} \qquad \left\{ \begin{array}{l} \text{DIRAC} \\ g = 2 \end{array} \right.$$

FOR AN ELEMENTARY POINTLIKE PARTICLE

THE BNL EXPERIMENT E821 IS AIMING TO CHALLENGE THE STANDARD MODEL BY AN ACCURATE MEASUREMENT OF

$$a_\mu = \frac{g-2}{2}$$

a_{μ^+} HAD AN ACCURACY OF 10 ppm IN THE PREVIOUS OLD (~ 20 YEARS AGO) CERN EXPERIMENT.

NOW IT IS 0.7 ppm !

AT THIS PRECISION LEVEL, a_{μ^+} IS SENSITIVE TO NEW PHYSICS CORRECTIONS WHICH HAVE THE SIZE OF THE WEAK CORRECTIONS. NOTE THAT $a_{\mu^+}^{exp} > a_{\mu^+}^{th}$

MAY BE SUSY IS AROUND THE CORNER ??

FUTURE : MUST RELEASE μ^-

WARNING : WILL HAVE TO IMPROVE ON THEORETICAL CALCULATIONS AND THE USE OF DATA TO EVALUATE HADRONIC CORRECTIONS

WHAT ARE THE SPIN PROPERTIES OF THE POMERON?

(B. KOPELIOVICH)

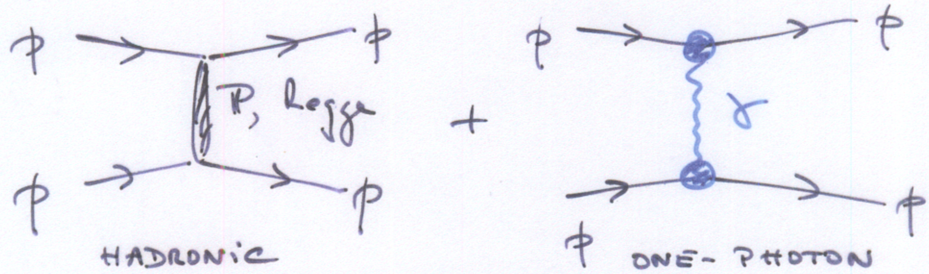
PREJUDICE FOR SIMPLICITY: ONLY NON-FLIP

$F_{++}^{\mathbb{P}} \neq 0$ BUT $F_{+-}^{\mathbb{P}} = 0$

DIFFICULT TO ACCESS

- AT $t=0$ DIFFERENCE OF σ_{tot} IN PURE SPIN STATES (A CLEAR TASK FOR $pp \to pp$ AT RHIC)
- AT $t \neq 0$ H.E. POLARIZATION MEASUREMENTS (ALSO $pp \to pp$)

THIS QUESTION BECOMES VERY RELEVANT FOR THE USE OF COULOMB-NUCLER INTERFERENCE (CNI) IN $pp \to pp$ AS A POLARIMETER IN SMALL t REGION



$10^{-3} \leq t \leq 10^{-2}$

FIRST RESULTS FROM E704 (INCONCLUSIVE)

RECENT RESULTS FROM E950 $r_5 \neq 0$ (F_{+-}/F_{++})

SEE ALSO VERY NEW RHIC RESULTS

J. Tojo et al. The E950 experiment at BNL

2002

$\mathrm{Re}\, r_5 = 0.088 \pm 0.058\ (0.042$

$\mathrm{Im}\, r_5 = -0.161 \pm 0.226\ (0.114)$

$P_{lab} = 21.7$ GeV/c

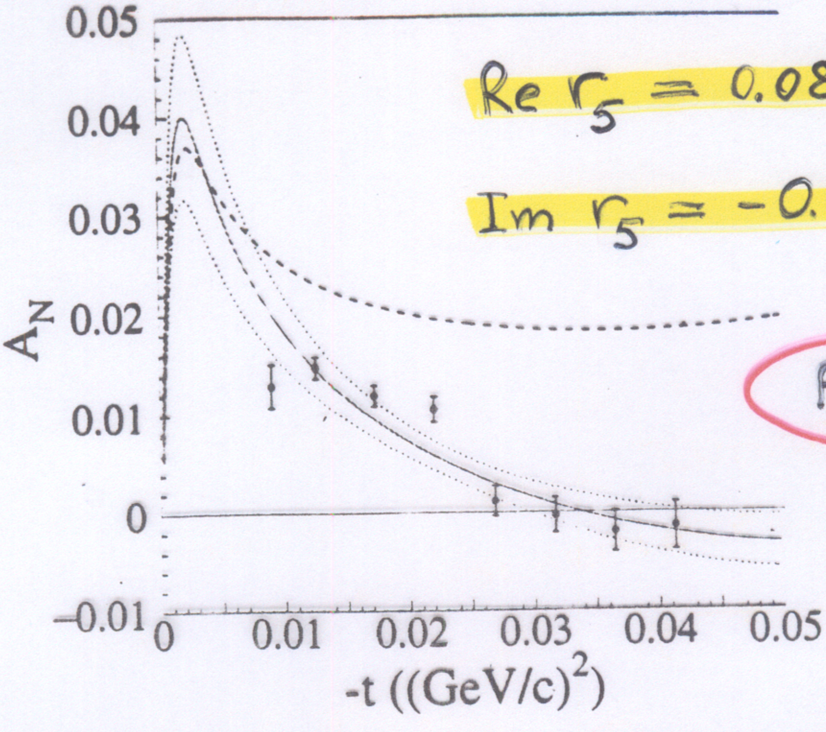


FIG. 3: The analyzing power, $\mathcal{A}_N$, for pC elastic scattering in CNI region. The error bars on the data points are statistical only. The solid line is the fitted function from theory [4]. The dotted lines are the 1-sigma error band of the fitting result. The dashed line is the theoretical function with no hadronic spin-flip amplitude ($r_5 = 0$).

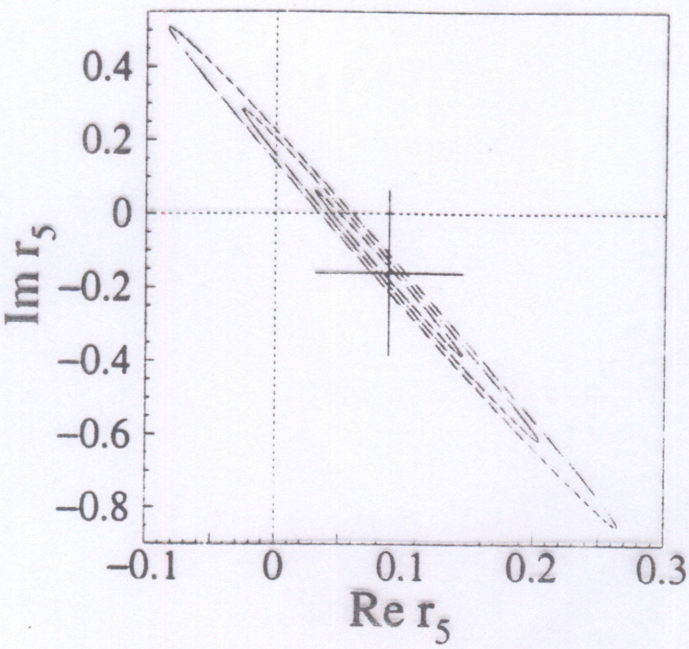
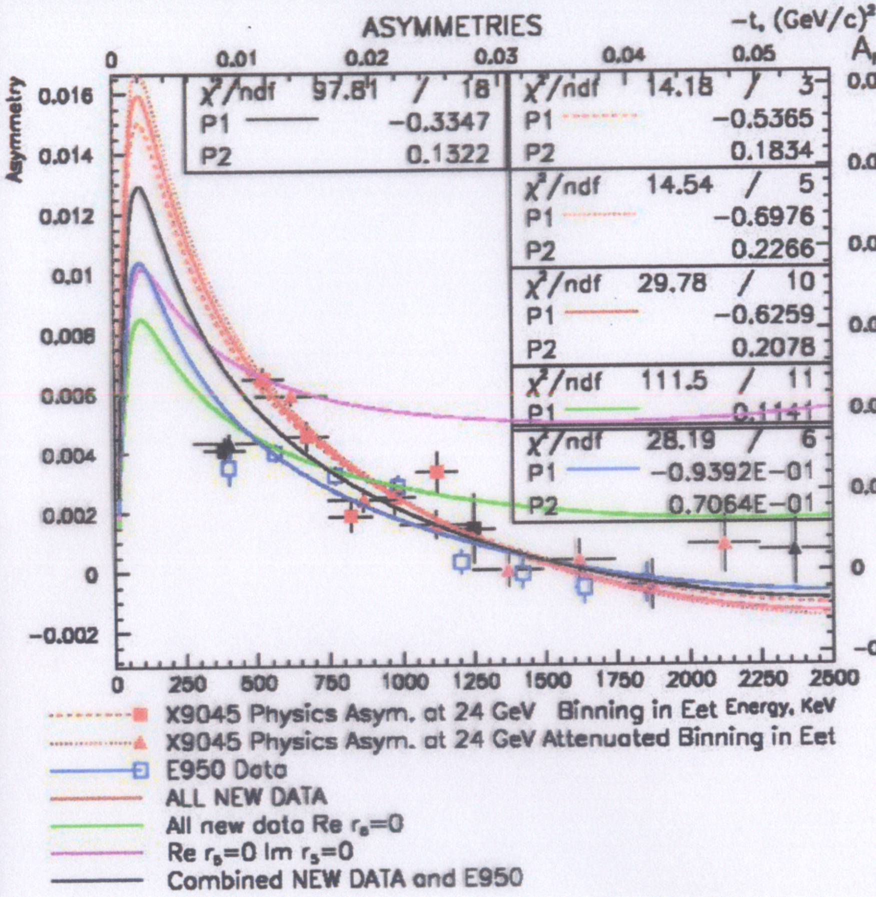
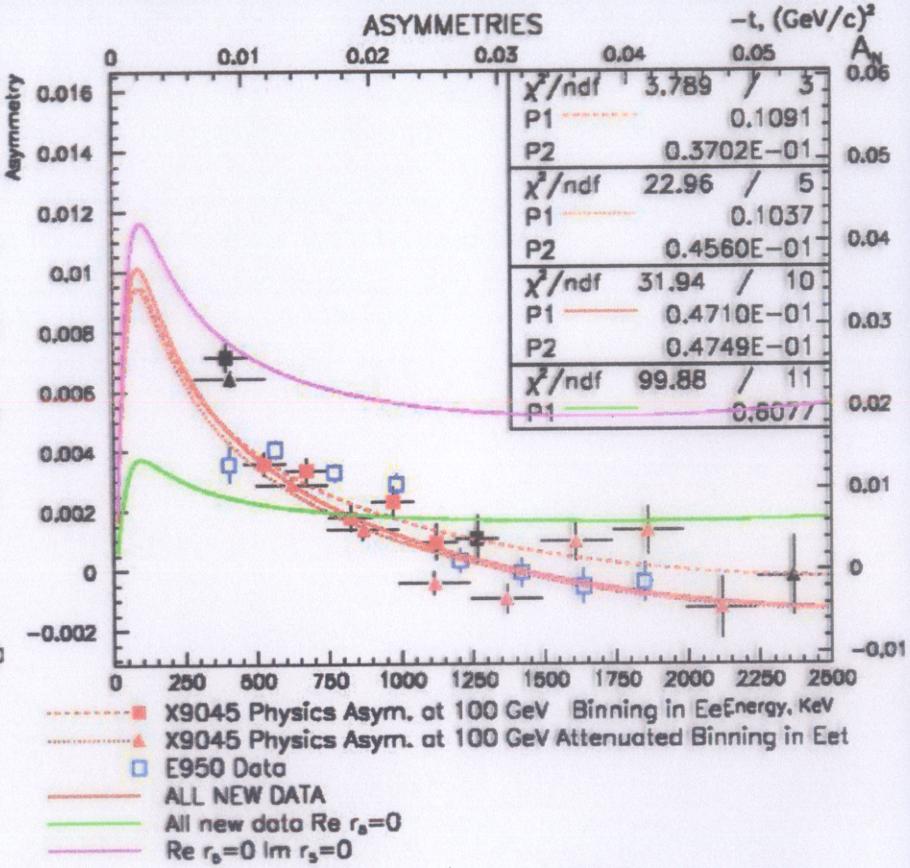


FIG. 4: Ratio of hadronic spin-flip to non-flip amplitude, r_5, and the 1-, 2- and 3-sigma contours of χ^2.

Results





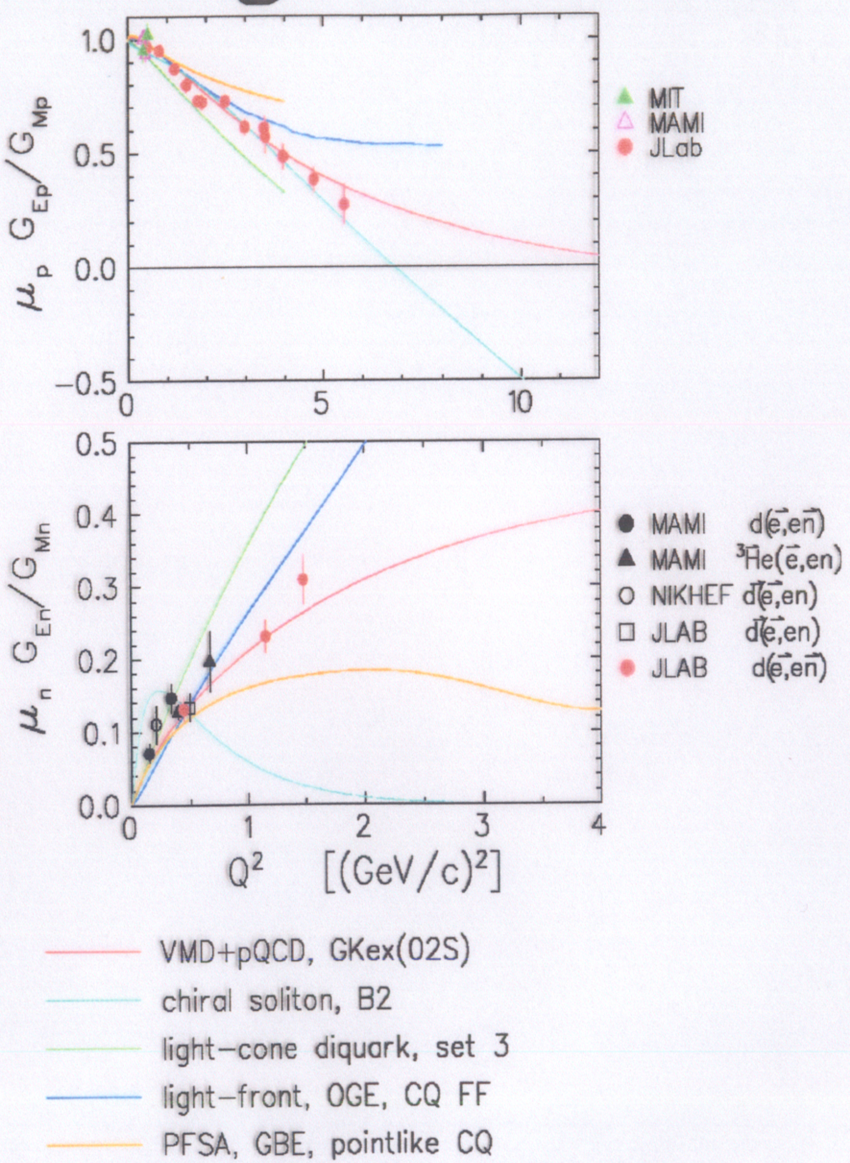
$$r_5 = \frac{m_p}{\sqrt{-t}} \cdot \frac{f_{+-}}{\operatorname{Im} f_{++}} \qquad \rho = \frac{\operatorname{Re} f_{++}}{\operatorname{Im} f_{++}} \qquad f = \frac{F_H}{F_{EM}}$$

$$A = \frac{\sqrt{-t}}{m_p} \cdot f \cdot \frac{\frac{t_c}{t}\left((\mu-1)(1-\delta\rho) - 2(\operatorname{Im} r_5 - \delta \operatorname{Re} r_5)\right) - 2f(\operatorname{Re} r_5 - \rho \operatorname{Im} r_5)}{\left(\frac{t_c}{t}\right)^2 - 2f\frac{t_c}{t}(\rho+\delta) + f^2\left(1+\rho^2+t\frac{|r_5|^2}{m_p^2}\right)}$$

- Single energy fits for $\operatorname{Re} r_5$ & $\operatorname{Im} r_5$ with L.Trueman&B.Kopeliovioch formulas with running ρ and f

Models vs. Electromagnetic Ratio

- Chiral soliton predicted linear g_p, but needs large boost mass for high Q^2 and does not fit g_n.
- VMD+pQCD fits well
- G_{En} particularly sensitive to scalar/vector diquark mixture or to small components of CQ wave function
- Deviations for CQ grow with Q^2, especially for neutron.
- High Q^2 data for g_n important!



IS THE RIDDLE OF THE PROTON SPIN STRUCTURE SOLVED ?

A FUNDAMENTAL SUM RULE

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta g + L_q + L_g$$

WHERE $\Delta\Sigma = \sum_i (\Delta q_i + \Delta\bar{q}_i)$

IN NAIVE PARTON MODEL $\Delta\Sigma = 1$, $\Delta g = 0$
AND IGNORE L_q, L_g.

1988 EMC DATA ⇒ ONE BIG SURPRISE
$\Delta\Sigma$ SMALL (FIRST MOMENT)

THIS WAS INTERPRETED AS THE FACT THAT
$\Delta\Sigma_{sea}$ IS LARGE AND NEGATIVE SO

$$\Delta\Sigma = \Delta\Sigma_{val} + \Delta\Sigma_{sea} \sim 0$$

IN DIS INCLUSIVE NO WAY TO MAKE THIS SEPARATION AND ALSO FLAVOR SEPARATION BECAUSE ONE MEASURES

$$A_1(x) \simeq g_1(x)/F_1(x) \quad \text{AND} \quad g_1(x) = \frac{1}{2}\sum_i e_i^2 (\Delta q_i(x) + \Delta\bar{q}_i)$$

ONE WAY TO DO IT IS TO MEASURE SEMI INCLUSIVE DIS

2000 - 2002 HERMES DATA ⇒ ANOTHER BIG SURPRISE
$\Delta\Sigma_{sea}$ SMALL

BEGIN TO SEE THE DIFFERENT COMPONENTS

$\Delta s(x) > 0$!! $\Delta\bar{u}(x) - \Delta\bar{d}(x) > 0$

$$g_1^p(x,Q^2) = \frac{1}{2} \sum_i e_i^2 \left[\Delta q_i(x,Q^2) + \Delta \bar{q}_i(x,Q^2) \right]$$

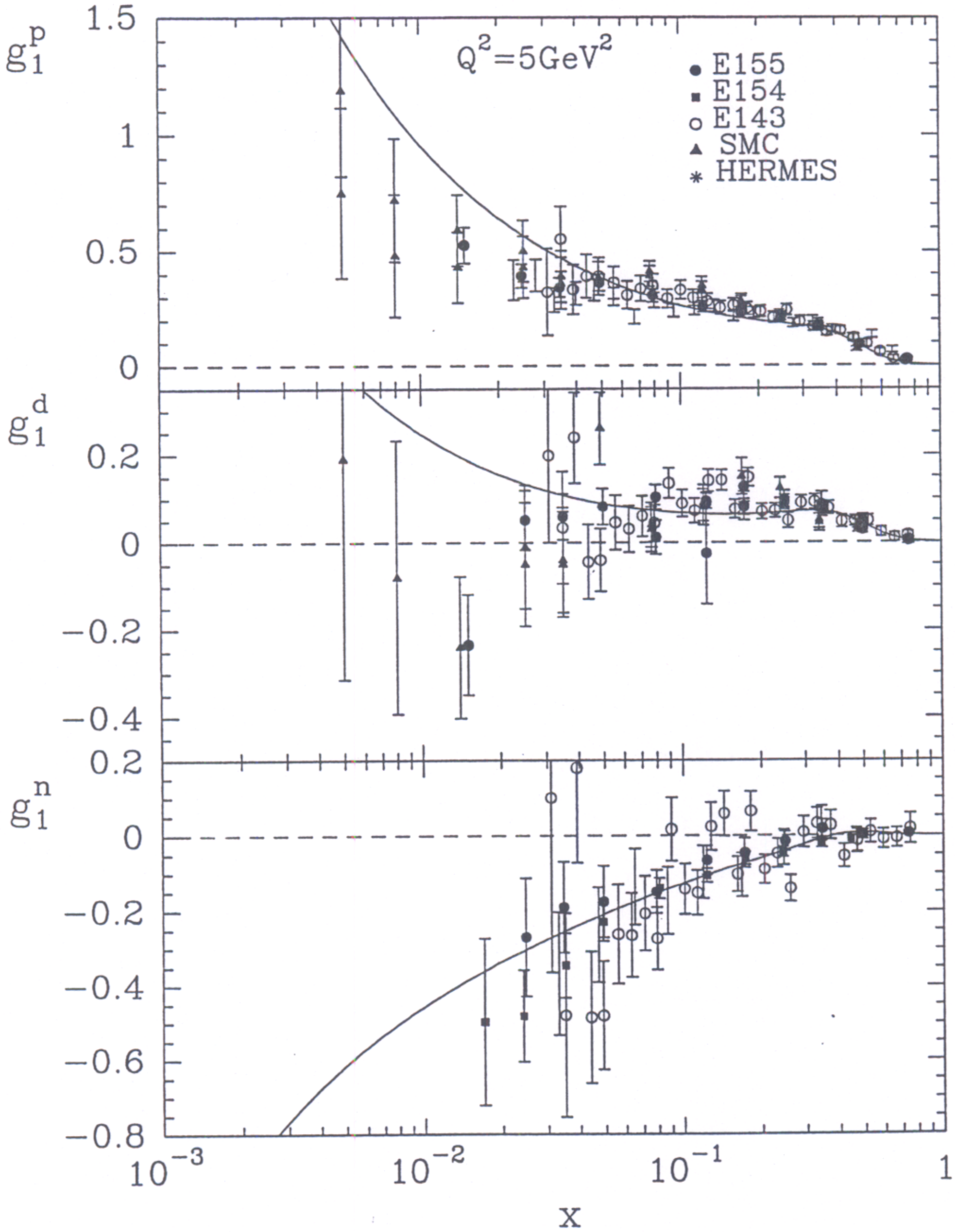


Figure 31: $g_1^p(x, Q^2)$ as function of x for different Q^2 values, from E155, E154, E143, SMC, HERMES experiments. The curve corresponds to a model prediction at $Q^2 = 5\text{GeV}^2$.

THIS FLAVOR SEPARATION CAN BE BETTER CHECKED AT RHIC IN $W^{\pm}$ PRODUCTION IN LIMITED X REGIONS i.e.

$0.2 \leq x \leq 0.6$ FOR $\Delta u/u$, $\Delta d/d$ ($\sqrt{s} = 500$ Ge

$0.045 \leq x \leq 0.1$ FOR $\Delta\bar{u}/\bar{u}$, $\Delta\bar{d}/\bar{d}$

ALTHOUGH A MAJOR EFFORT WAS DONE SINCE 1988 TO EXPLORE THE SMALL X REGION FOR THE PURPOSE OF CHECKING THE BJ SUM RULE, IT IS ALSO IMPORTANT TO HAVE ACCURATE DATA IN LARGE X REGION

NEW JLAB DATA ON A_1^n AND PROSPECT

FINALLY IT IS CRUCIAL TO KNOW $\Delta g(x)$ AND THERE ARE SEVERAL WAYS TO GET IT

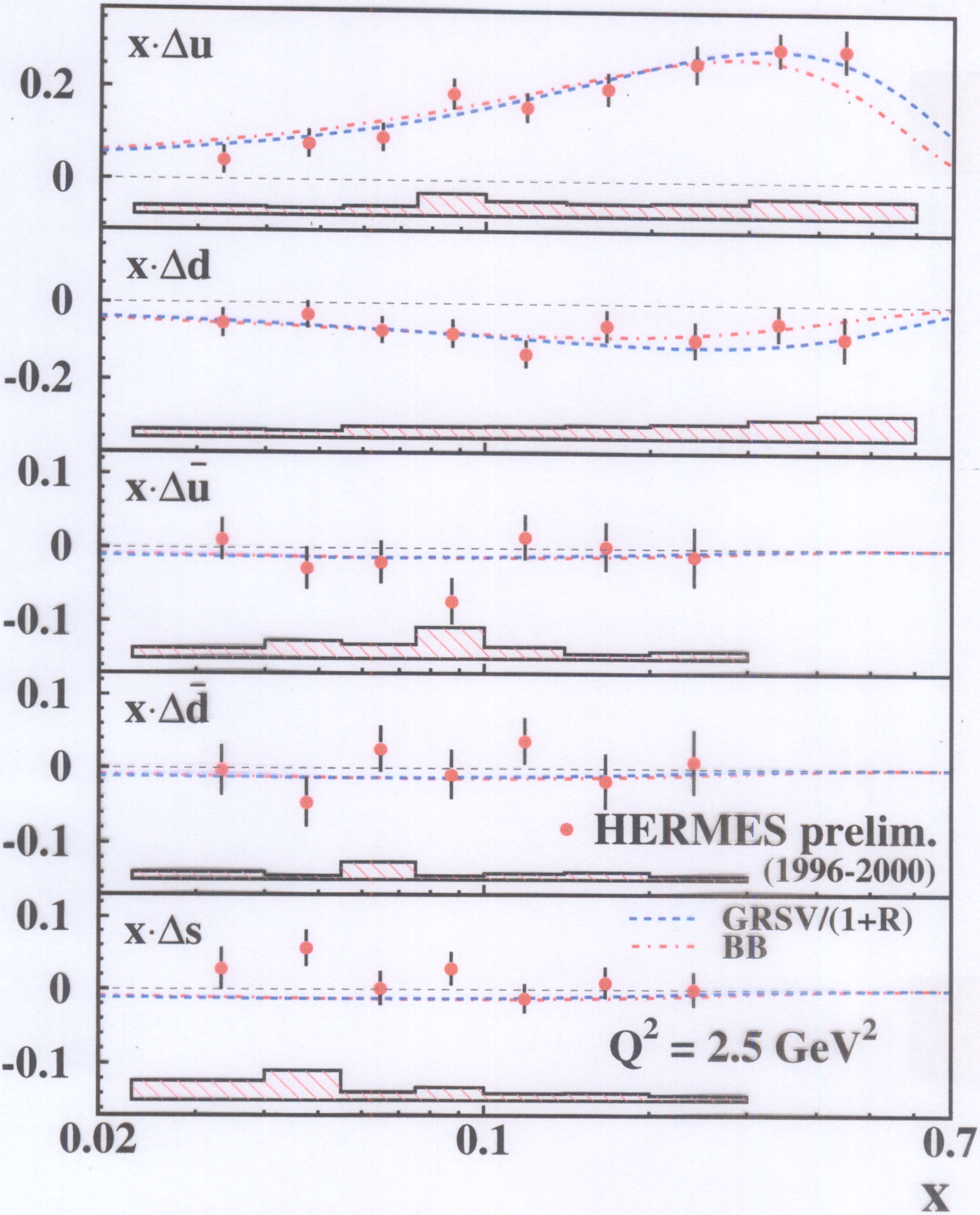
RHIC
- PROMPT PHOTON PRODUCTION $\vec{p}\vec{p} \to \gamma X$ ($\vec{p}\vec{p} \to \gamma\, jet\, X$
- HIGH p_T JET $\vec{p}\vec{p} \to jet\, X$
- HEAVY FLAVORS $\vec{p}\vec{p} \to Q\bar{Q}X$

COMPASS CHARM PRODUCTION

SPECULATIVE

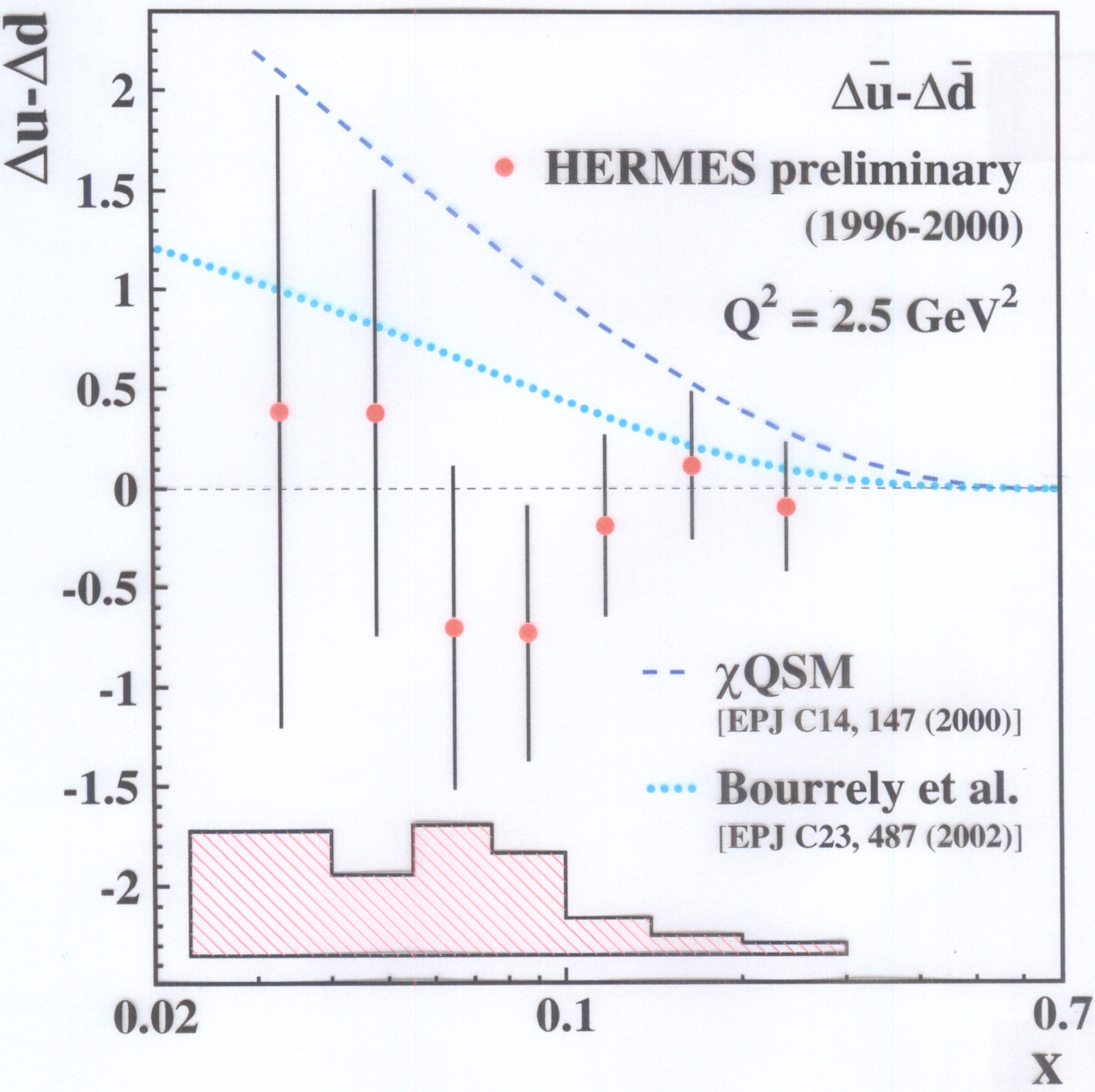
NOTE IN $\vec{p}\vec{p} \to jet\, X$ IF $\Delta g > 0$ ONE FINDS $A_{LL} > 0$ BECAUSE $\hat{a}_{LL}^{ij}$ FOR ALL SUBPROCESSES ARE POSITIVE. HOWEVER FOR THE PRODUCTION OF SUSY PARTICLES $gg \to \tilde{g}\tilde{g}$, $qg \to \tilde{q}\tilde{g}$, etc... $\hat{a}_{LL}^{ij} = -100\%$ SO THIS COULD REDUCE THE EFFECT

Polarised Quark Densities at LO



- Unpol. PDF: CTEQ5 LO
- Strange sea polarisation: $\Delta s \gtrsim 0$

Symmetry of the Polarised Light Sea



- The HERMES data are consistent with flavour symmetry
- The data disfavour χQSM of Dressler *et al.*

PREDICTIONS FOR ASYMMETRIES FOR $W^{\pm}$, Z PRODUCTION AT RHIC

IN L.O.

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

$A_L^{PV}(W^-)$ $(u \leftrightarrow d)$

$A_L^{PV}(Z^0)$ INVOLVES a, b COUPLING BUT SIMILAR EXPRESSION

$$A_{LL}^{PC}(W^+) = -\frac{\Delta u(x_a)\,\Delta\bar{d}(x_b) + \Delta\bar{d}(x_a)\,\Delta u(x_b)}{u(x_a)\,\bar{d}(x_b) + \bar{d}(x_a)\,u(x_b)}$$

$A_{LL}^{PC}(W^-)$ $(u \leftrightarrow d)$

$A_{LL}^{PC}(Z^0)$

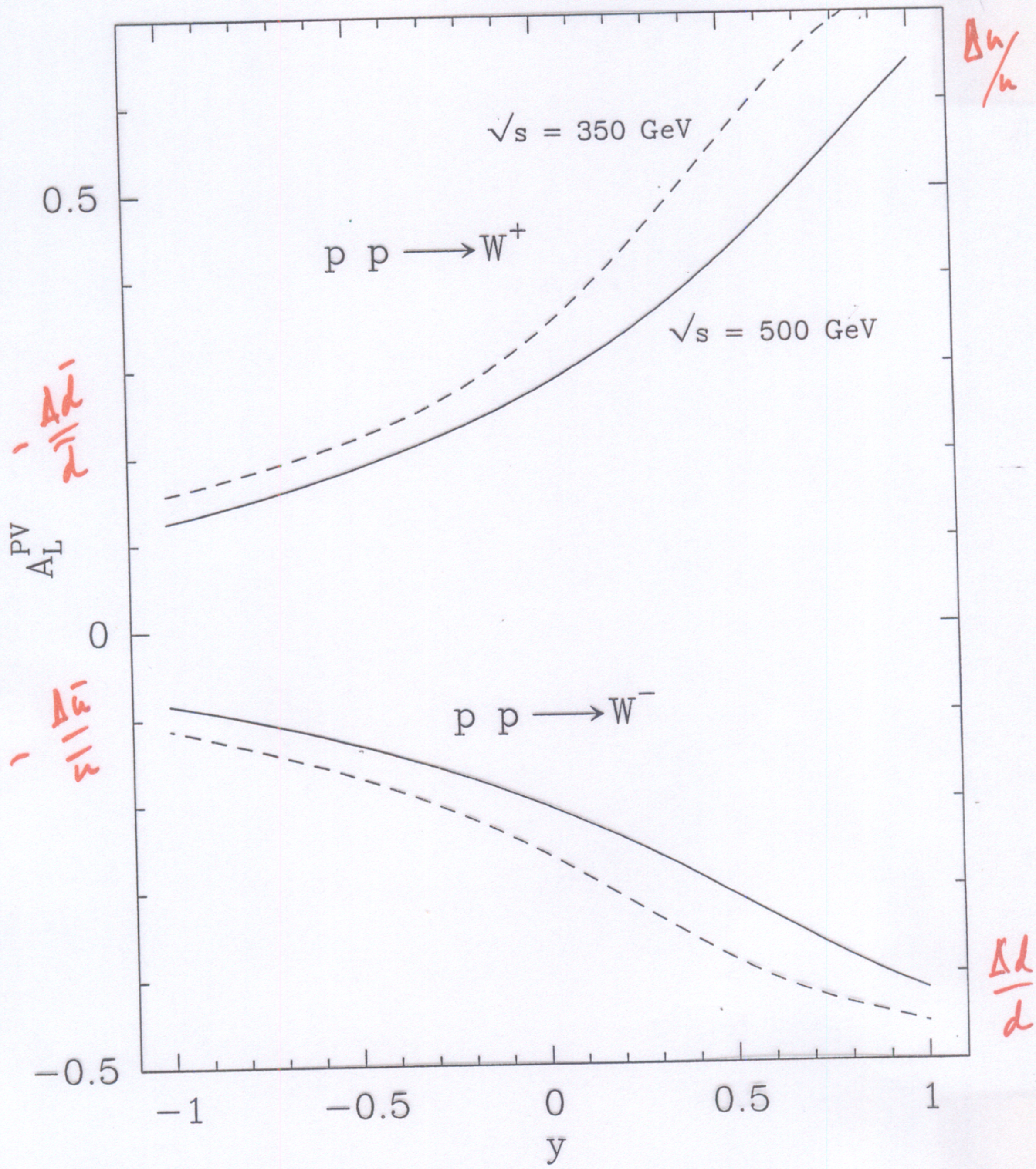


Figure 44: The parity violating asymmetry A_L^{PV} for $pp \to W^{\pm}$ production versus the rapidity y at $\sqrt{s} = 350, 500$GeV (dashed, solid).

EPJ C23, 487 (2001)

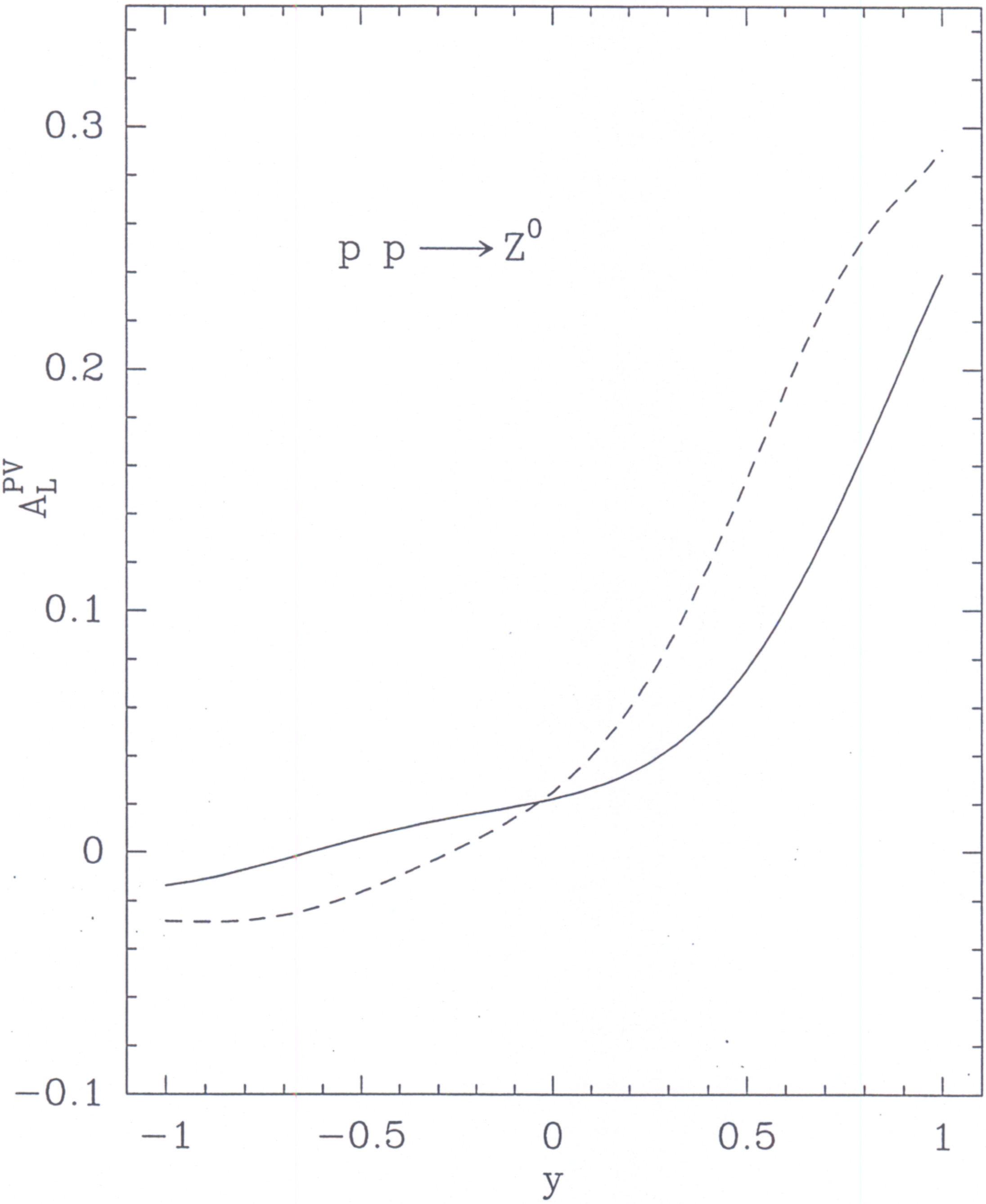


Figure 48: The parity violating asymmetry A_L^{PV} for $pp \to Z^0$ production versus the rapidity y at $\sqrt{s} = 350, 500$GeV (dashed, solid).

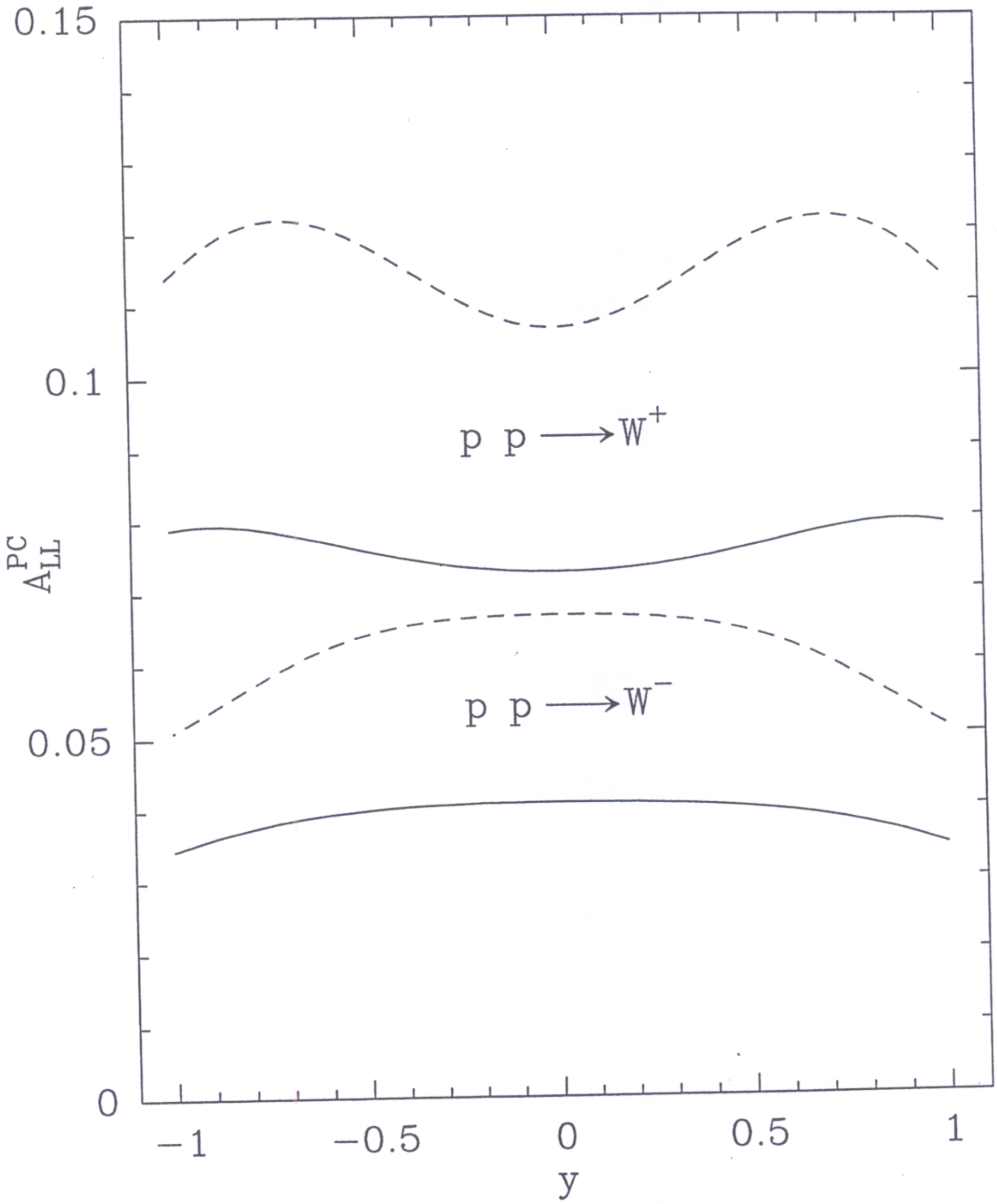
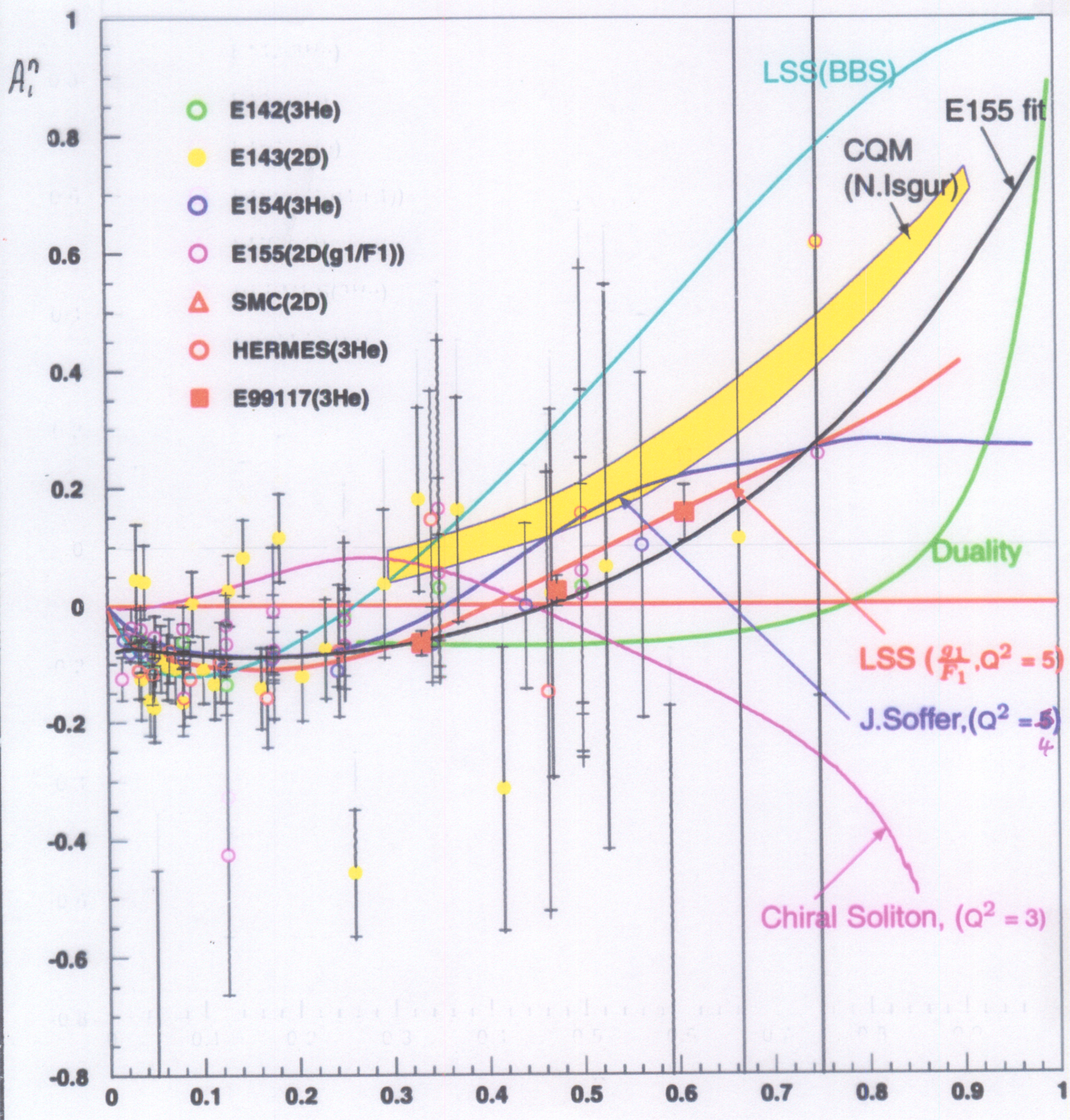


Figure 47: Parity conserving double helicity asymmetry A_{LL}^{PC} for $pp \to W^{\pm}$ production versus the rapidity y at $\sqrt{s} = 350, 500\text{GeV}$ (dashed, solid) .

JLAB E99-117

A_1^n Preliminary Result

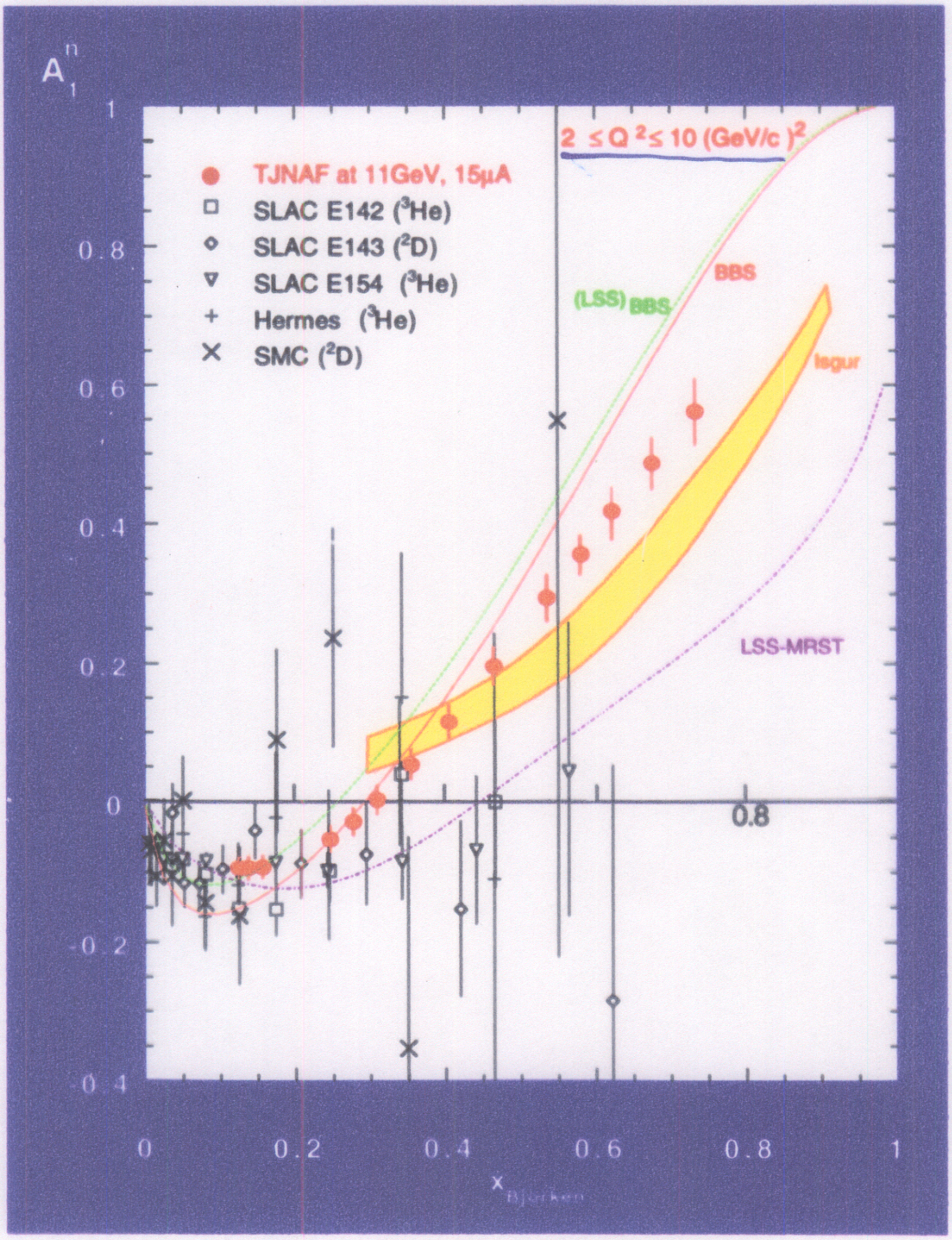
T. Averett



T. Averett

A_1^n @ JLab 12 GeV Upgrade

- Precision measurement of spin asymmetry in valence quark region
- Decisive test of pQCD vs quark model, insight to quark-gluon wavefunctions



- **prompt photon (plus jet) production**:
  NLO: Gordon, Vogelsang, Contogouris et al., Frixione, Vogelsang

✓ $qg \to q\gamma$ dominant → *the* tool to pin down the gluon

✓ can be measured by PHENIX and STAR

✓ fragmentation contr. reduced if isolation is imposed
[isolation necessary to reduce $\pi^0 \to \gamma\gamma$ background]

✓ considerable theoretical efforts to go beyond NLO
[soft gluon/threshold (and k_T) resummations: Laenen et al.; Catani et al.; Li; Kidonakis Owens; Laenen, Sterman, Vogelsang]

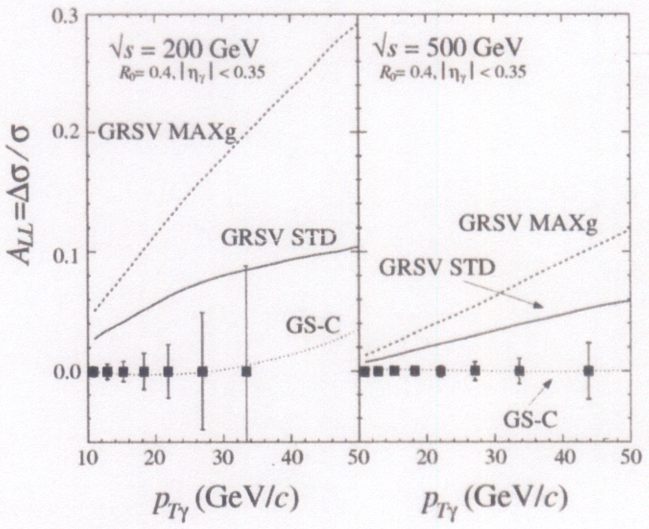
× some trouble with unpol. fixed target data; collider ✓

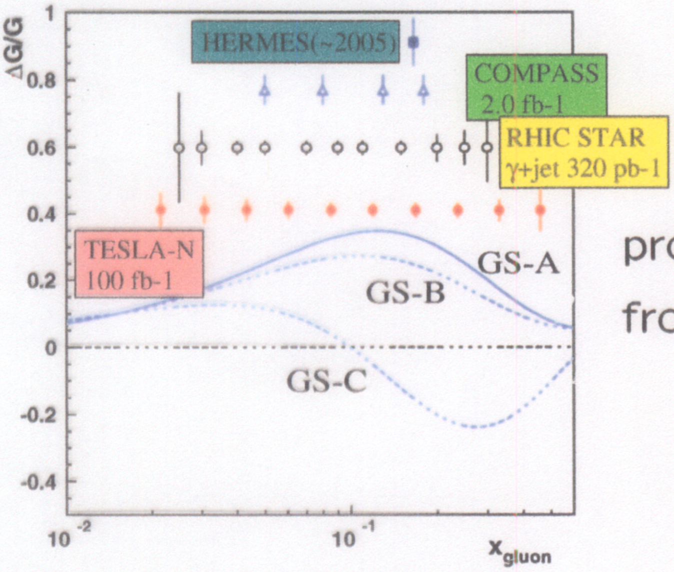
$A_{LL}^{\gamma}(p_T)$ for PHENIX:
Frixione, Vogelsang

→ expected sensitivity to Δg

not shown:

- reduced scale dependence in NLO ✓





projected accuracy for $\Delta g/g$ from γ + jet at STAR

- **high-p_T jet production**:

  NLO: de Florian, Frixione, Signer, Vogelsang

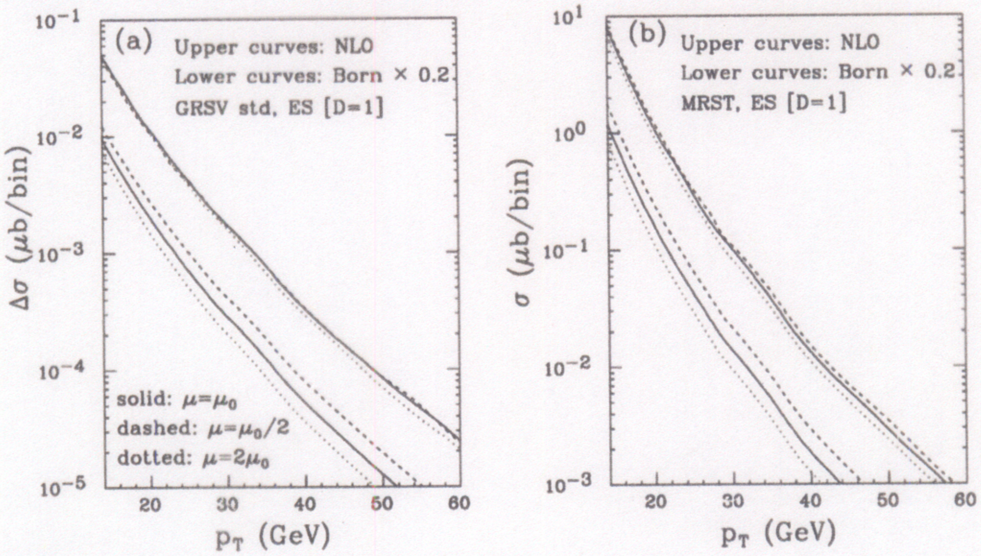
✓ copiously produced at high energies → good statistics

✓ theoretically well understood in unpolarized case

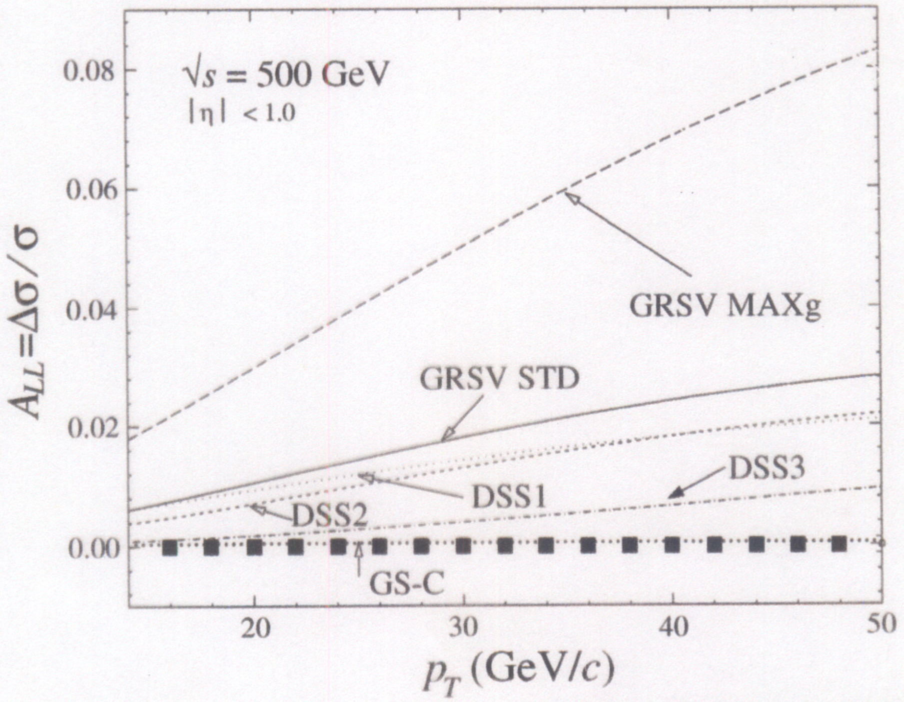
✓ good sensitivity to Δg

✓ NLO essential for realistic jet description

✓ μ_f dependence strongly reduced in NLO:



expectations for A_{LL} for STAR:



(figures taken from de Florian et al.)

- **leading high-p_T pions as jet surrogates:**

NLO: Jäger, MS, Vogelsang; de Florian

✓ also copiously produced

✓ don't have to see a jet → can go to lower p_T

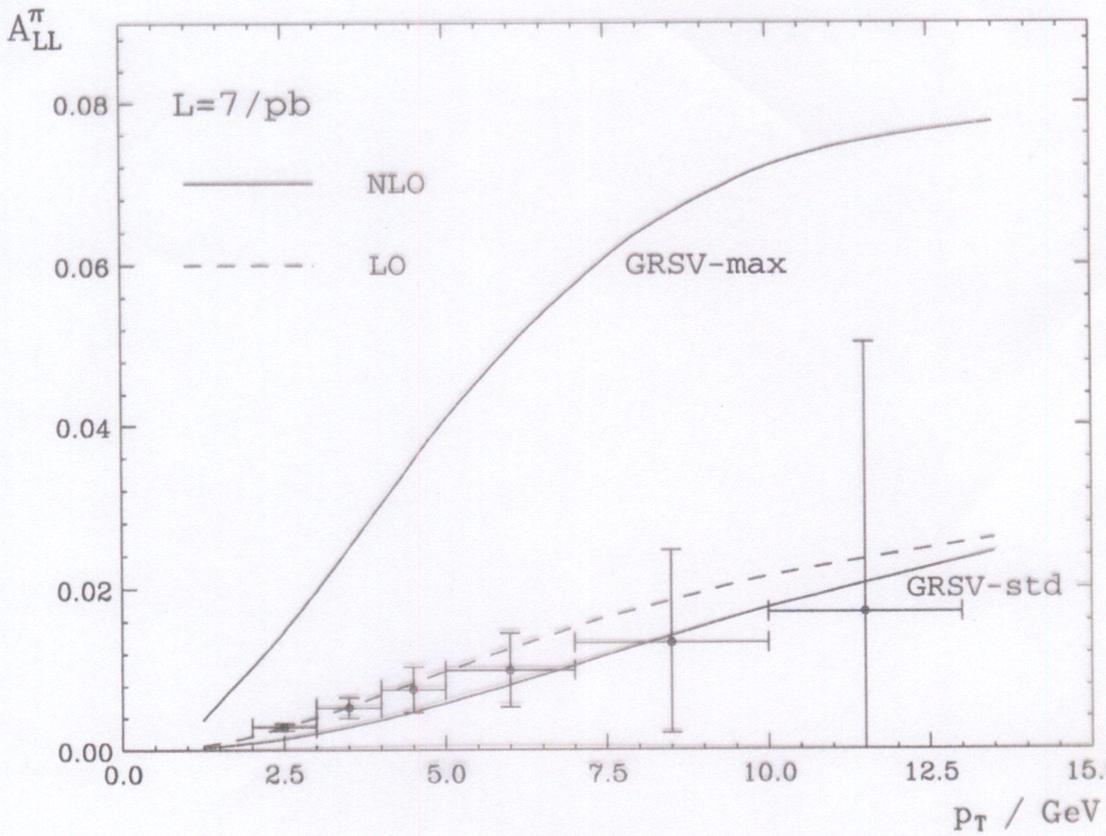
✓ perhaps better suited than jets at $\sqrt{S} = 200$ GeV

× knowledge of frag. fcts. not fully satisfactory

recent progress: Kretzer; Christova, Kretzer, Leader

very moderate luminosity assumed!

↓



Jäger, MS, Vogelsang

estimate of statistical errors: $\delta A \simeq \frac{1}{P_1 P_2} \times \frac{1}{\sqrt{\mathcal{L}\sigma_{\rm bin}\varepsilon_{\rm eff}}}$

[with $P_1 = P_2 = 0.5$ (beam pol.) and $\varepsilon_{\rm eff} = 1$ (detection efficiency)]

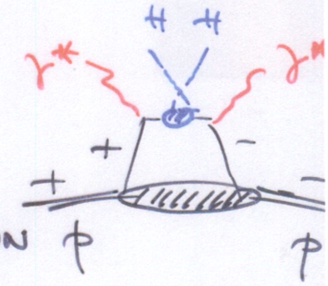
TRANSVERSITY OF A QUARK IN THE NUCLEON ...

$h_1^q(x, Q^2)$ ($\delta q(x, Q^2)$) A FUNDAMENTAL LEADING TWIST PARTON DISTRIBUTION

NOT ACCESSIBLE IN DIS BECAUSE CHIRAL ODD

BUT CAN BE MEASURED

- IN SI DIS $e p^\uparrow \to e H(\vec{k}_T) X$



SO MEASURE THE PRODUCT OF h_1^q WITH A CHIRAL ODD FRAGMENTATION FUNCTION.

THIS EFFECT HAS BEEN ALREADY UNCOVERED IN THE HERMES AZIMUTHAL ASYMMETRY A_{UL}

SHOULD BE CONFIRMED AND LARGER WITH A TRANSVERSE TARGET

- IN pp COLLISIONS AT RHIC

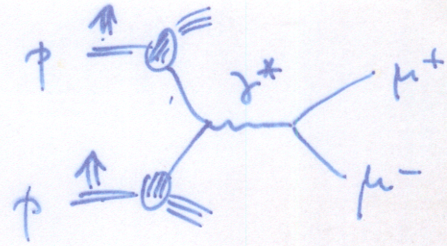
  A_{TT} IN DIMUON PRODUCTION EXPECTED TO BE SMALL

  ALSO ANTICIPATE STRONG DILUTION OF A_{TT} IN GLUON INDUCED PROCESSES LIKE JET PRODUCTION OR PROMPT PHOTON PRODUCTION

$$|A_{TT}| \ll A_{LL}$$

MUST BE CHECKED

$p^{\uparrow} p^{\uparrow} \rightarrow \mu^+ \mu^- X$



$$A_{TT} = \hat{a}_{TT} \frac{\sum_q e_q^2 \, h_q(x_1, M^2) \, h_{\bar{q}}(x_2, M^2) + (1 \leftrightarrow 2)}{\sum_q e_q^2 \, q(x_1, M^2) \, \bar{q}(x_2, M^2) + (1 \leftrightarrow 2)}$$

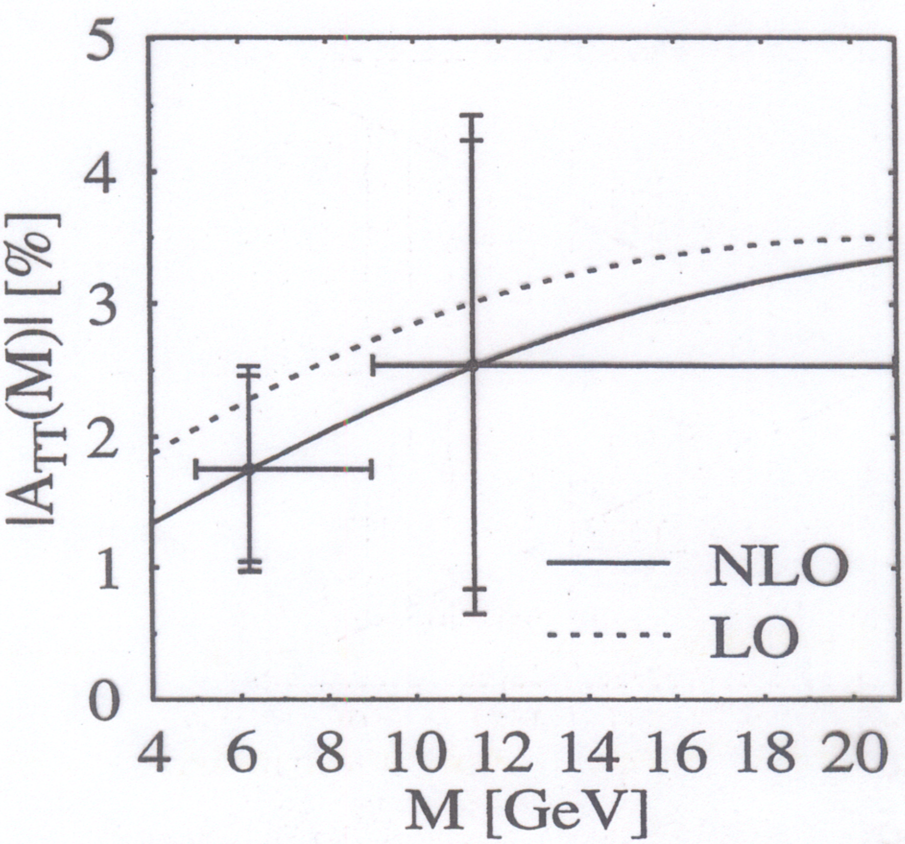


Figure 17: Next-to-leading-order transverse-spin asymmetry for Drell-Yan dimuon production at $\sqrt{s} = 200$ GeV [121].

O. MARTIN, A. SCHÄFER, A. STRATMANN, W. VOGELSANG, PHYS. REV. D57 3084 (1998) and D60, 117502 (1999)

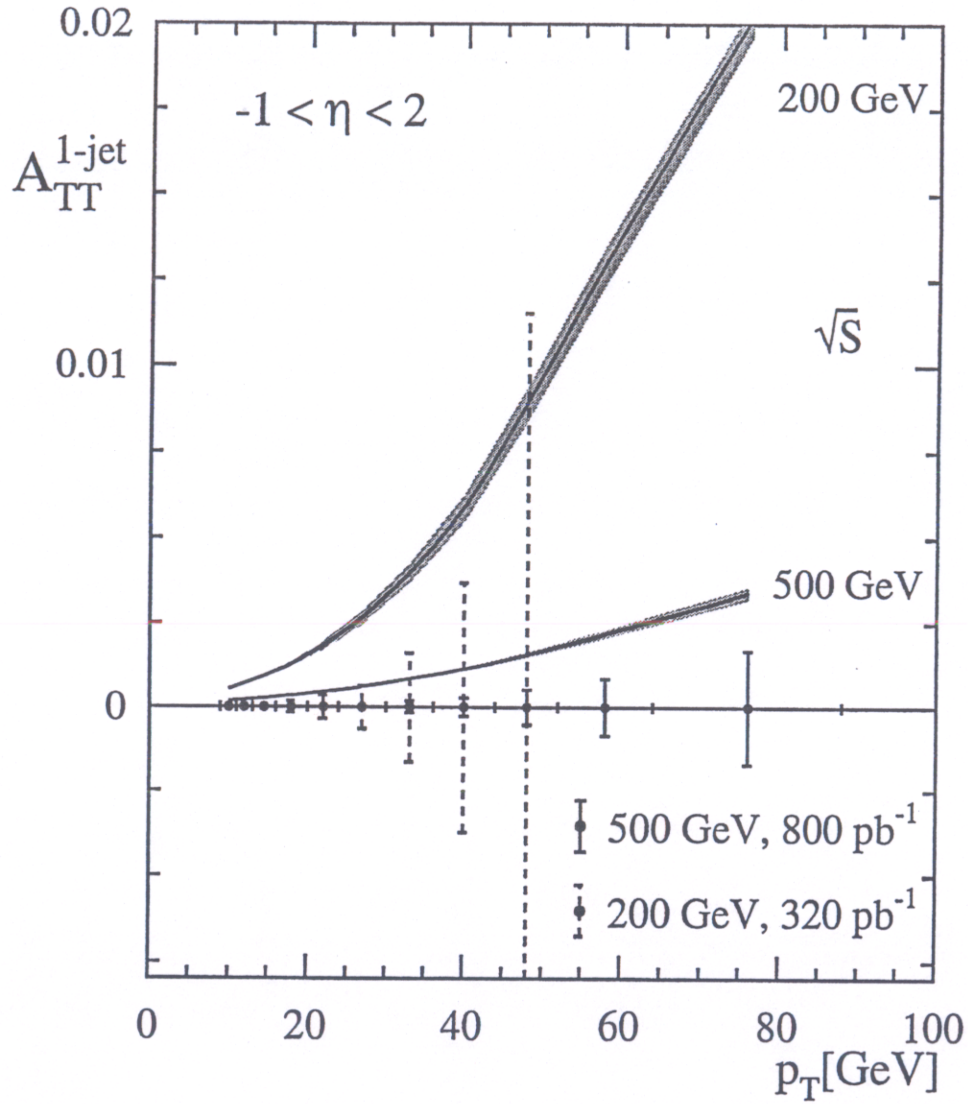


Figure 1: "Maximally possible" $A_{\rm TT}$ for single-inclusive jet production at RHIC c.m.s. energies of 200 GeV and 500 GeV as a function of p_T. Jet rapidities are integrated over the detector acceptance $(-1 \leq \eta \leq 2)$. The shaded bands represent the theoretical uncertainty in $A_{\rm TT}$ if μ_F is varied in the range $p_T/2 \leq \mu_F \leq 2p_T$. Also indicated as "error bars" is the expected statistical accuracy for certain bins in p_T.

J.S., M. STRATMANN, W. VOGELSANG, PRD65, 114024 (2002)

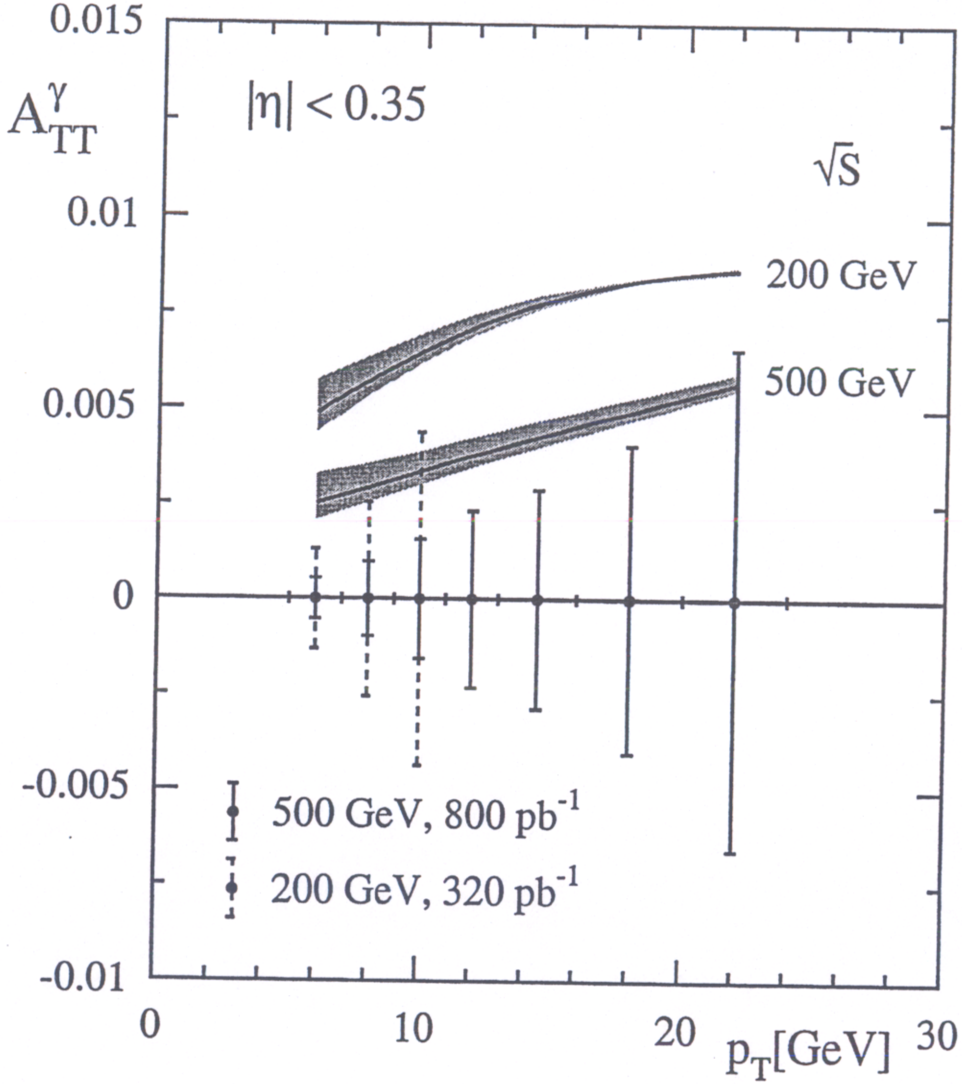


Figure 2: Same as in Fig. 1 but now for prompt photon production. The photon rapidity has been integrated over the range $|\eta| \leq 0.35$ accessible at RHIC, and only half of the full azimuth is taken into account.

J.S., M. STRATMAN, W. VOGELSANG, PRD 65, 114024 (2002)

SINGLE TRANSVERSE SPIN ASYMMETRIES

$$A_N(\sqrt{s}, x_F, p_T) = \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow} \qquad a^\uparrow + b \to c X \quad \text{or} \quad a + b \to e^\uparrow X$$

$$\sim \frac{\mathrm{Im}(f_+ f_-^*)}{|f_+|^2 + |f_-|^2}$$

THEY ARE NON-ZERO <u>ONLY</u> IF THERE IS AN INTERFERENCE BETWEEN A NON-FLIP AND A SINGLE-FLIP AMPLITUDES OUT OF PHASE

POSSIBLE MECHANISMS

- COLLINS FRAGMENTATION FUNCTION
- SIVERS FUNCTION (BELIEVE TO BE DEAD 10 YEARS BUT BACK INTO THE GAME !!)
- TWIST-THREE CORRELATOR
- TWO-PION INTERFERENCE FRAGMENTATION IN DIS

ON EXPERIMENTAL SIDE SEVERAL PIECES OF EVIDENCE

$p^\uparrow p \to \pi X$ (E704, BNL)

$p p \to \Lambda^\uparrow X$ (FNAL, ISR)

etc. . . .

<u>WARNING</u> MAKE SURE THE PROPOSED MECHANISM TO EXPLAIN A_N IS APPROPRIATE TO DESCRIBE THE UNPOLARIZED CROSS SECT (SHAPE AND MAGNITUDE) IN THE SAME KINEMATIC REGION $\sqrt{s}, x_F$

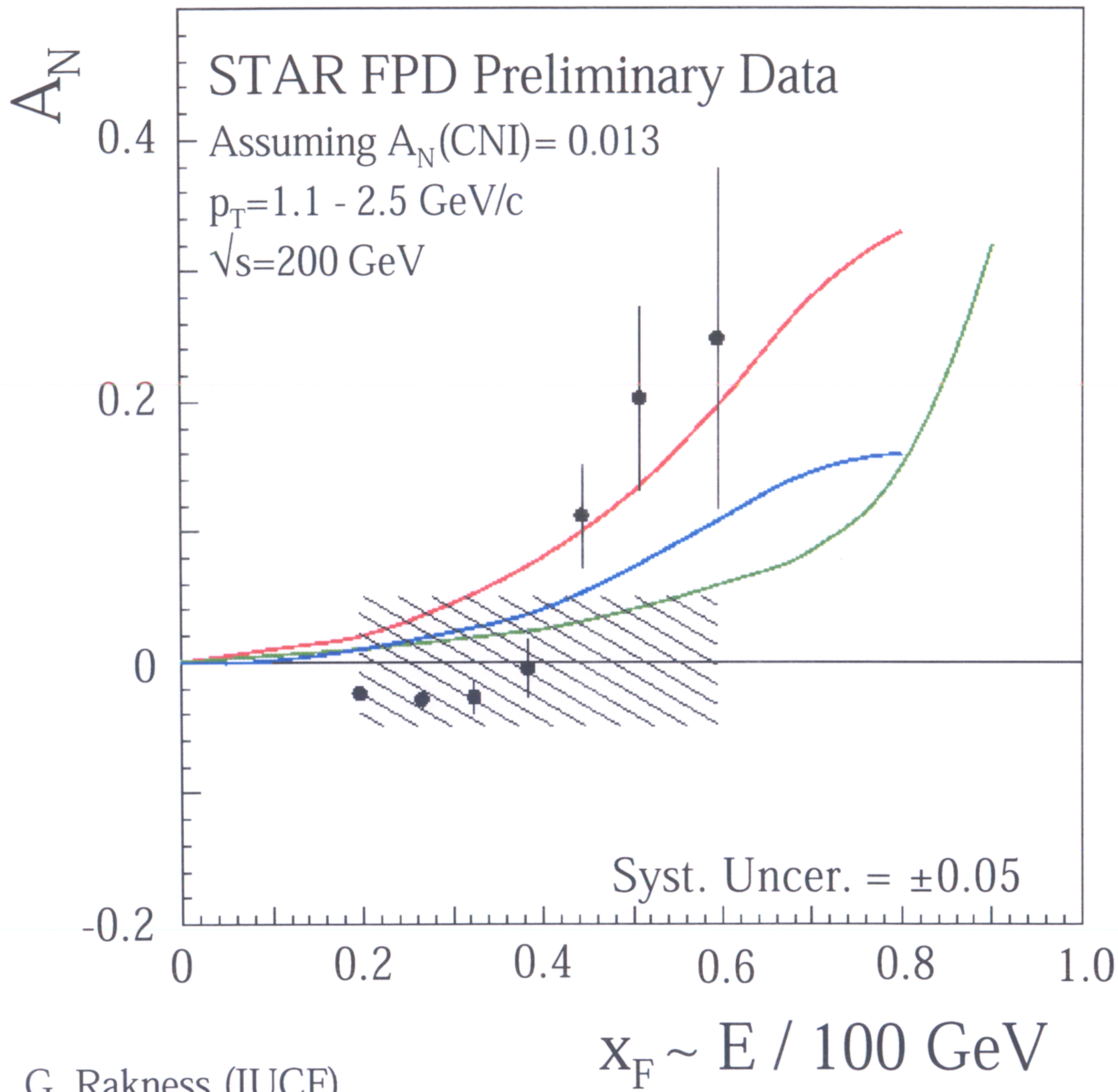
CANNOT CLAIM TO UNDERSTAND $N_R - N_L$ IF DON'T HAVE THE RIGHT $N_R + N_L$!!

ANOTHER SURPRISE AT RHIC $A_N(p^\uparrow p \to \pi$

BOTH LARGE $A_N(p^\uparrow p \to \pi^0)$

LOOKING FORWARD TO HIGHER p_T !!

$p_\uparrow + p \longrightarrow \pi^0 + X$



Theory predictions at p_T=1.5 GeV/c:

Collins effect
Anselmino, et al., private communication;
PRD 60 (1999) 054027.

Sivers effect
Anselmino, et al., private communication;
Phys. Lett. B442 (1998) 470.

Twist 3 effect
Qiu and Sterman, private communication;
PRD 59 (1998) 014004.

G. Rakness (IUCF)
SPIN 2002

STAR spin

Hunting for "New Physics" at RHIC

RHIC can be a tool to uncover physics beyond the SM

Parity-violating single-spin asymmetries:

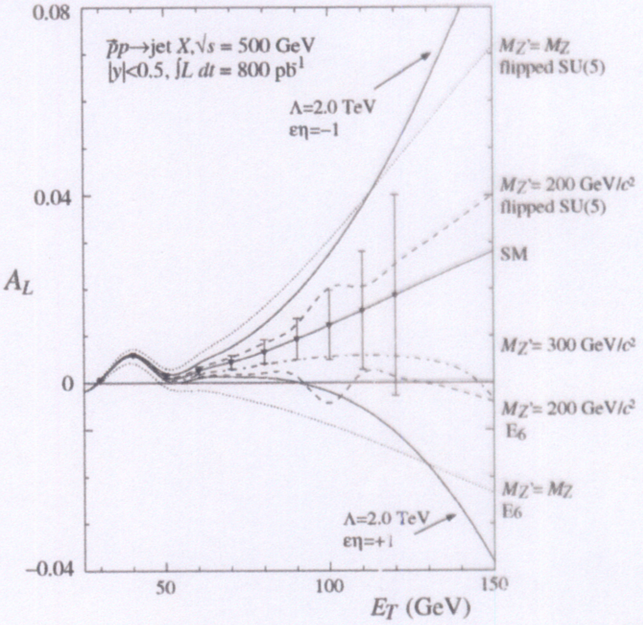
single jet production : $A_L^{PV} \equiv \dfrac{(d\sigma/dE_T)_- - (d\sigma/dE_T)_+}{(d\sigma/dE_T)_- + (d\sigma/dE_T)_+}$

idea: only *small* SM-contr. from QCD⊗EW interference
→ new parity-viol. interactions can lead to sizable effects
Bourrely, Guillet, Soffer; Tannenbaum; Taxil, Virey

- RHIC can be competetive with Tevatron run II — Virey
  (reduction of systematic errors in A_L^{PV})
- unique place to probe chiral structure of new interactions

candidates: Taxil, Virey

- contact interactions:
  $\sim \frac{g^2}{\Lambda^2} \bar{\Psi}\Gamma_\mu \Psi \bar{\Psi}\Gamma_\mu \Psi$
  'scale' $\Lambda > 2\,\text{TeV}$
- leptophobic Z':
  $M_Z \leq M_Z' \leq 1\,\text{TeV}$
  small mixing with SM Z



to be of any use need:

- $\sqrt{S} = 500\,\text{GeV}$, high luminosity & precision
- knowledge of pol. pdfs & SM 'background' in NLO
  Moretti, Ellis, Ross: EW 1-loop for $qg \to qg$, $q\bar{q} \to gg$, $gg \to q\bar{q}$
  Vogelsang: LL-threshold resummations for $\log(1 - x_T^2)$

CP VIOLATION IN HE COLLISIONS OF POLARIZED PROTONS

CONSIDER THE SINGLE TRANSVERSE ASYMMETRY $A_T^{\pm}$ IN

$$p^{\uparrow} p \to \ell^{\pm} \nu X$$

$$A_N = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

IN DRELL-YAN PICTURE WE HAVE

$$u + \bar{d} \to \ell^{+} + \nu$$

$$d + \bar{u} \to \ell^{-} + \bar{\nu}$$

$$A_N^{+} = \frac{\langle h_1^u(x_a)\, \bar{d}(x_b)\, \hat{a}_N^u \rangle + \langle h_1^{\bar{d}}(x_a)\, u(x_b)\, \hat{a}_N^{\bar{d}} \rangle}{\langle u(x_a)\, \bar{d}(x_b) \rangle + \langle \bar{d}(x_a)\, u(x_b) \rangle}$$

$$\sim \langle \frac{h_1^u}{u} \rangle\, \hat{a}_N^u \qquad (\text{if } h_1^{\bar{d}} \ll h_1^u)$$

IN $\not{R}_p$ MSSM ONE FINDS $\hat{a}_N^u \sim 0.1 \sin \varphi_{CP}$ FOR $\ell = \tau$. SO AT PROTON LEVEL IF $h_1^u/u \sim 0.5$

$$|A_N^{+}| \leq 5 \cdot 10^{-2}$$

A TENSOR MECHANISM LEADS TO A MUCH LARGER BOUND

SHOULD BE CHECKED AT RHIC

<u>NOTE</u> STANDARD A_N IN D-Y $\sim \frac{1}{Q}$

NO VERY SMALL AT W MASS

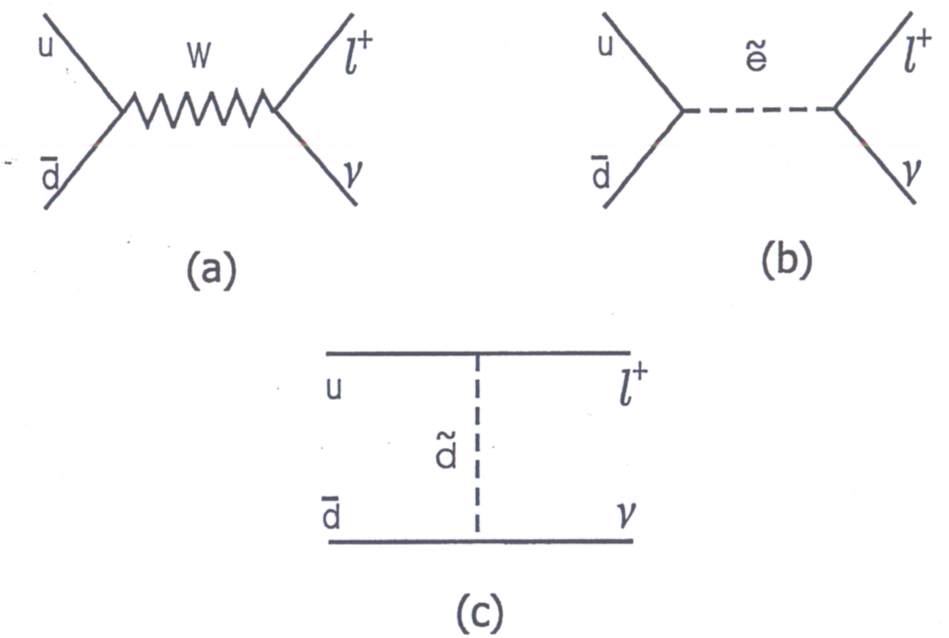
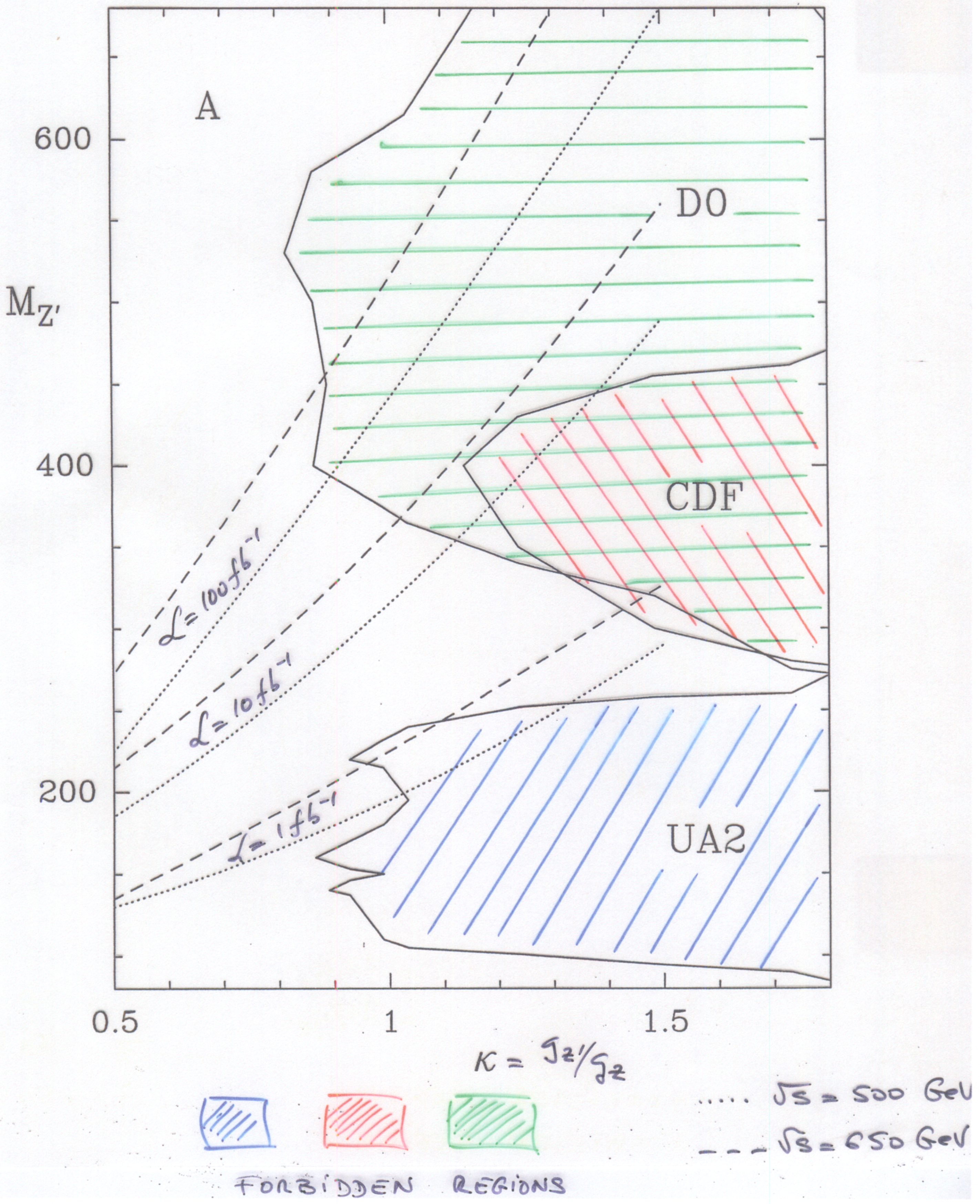


Fig. 1. (a) The standard model W-exchange and (b), (c) the R-parity violating supersymmetric contributions to the Drell–Yan lepton pair production.

In the SM the quark subprocesses (2) are mediated by the s-channel $W^{\pm}$-boson exchange, as shown in Fig. 1(a). For the case of interest $\hat{s} \gg m_q, m_l$ (m_q and m_l are the quark and lepton masses), and the corresponding helicity amplitudes are given by

$$(+-,--)_l = U_{ud}\frac{g^2}{2}\frac{m_l\sqrt{\hat{s}}}{\hat{s}-M_W^2}\sin\theta, \qquad (+-,-+) = -U_{ud}\frac{g^2}{2}\frac{\hat{s}}{\hat{s}-M_W^2}(1-\cos\theta). \tag{5}$$

THANKS TO THE POLARIZATION RHIC IS COMPETITIVE TO TEVATRON IN SPITE OF THE ENERGY DIFFERENCE



Fluctuations and Market Friction in Financial Trading

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(July 3, 2001)

We study the relation between stock price changes and the difference in the number of sell and buy orders. Using a soft spin model, we describe the price impact of order imbalances and find an analogy to the fluctuation-dissipation theorem in physical systems. We empirically investigate fluctuations and market friction for a major US stock and find support for our model calculations.

PACS numbers: 05.45.Tp, 89.90.+n, 05.40.-a, 05.40.Fb

.npredictable up and down movements in the ırket have always captured the interest and imag- ɟf investors. The scientific investigation of these :na started with Bachelier's comparison of stock ıamics with a random walk [1]. This study has ned in many respects [2]. Interest has been de- the precise shape of the distribution of returns :e of the logarithm of stock prices at different vhich is characterized by a high probability for :tuations [3–6].

t was realized that large price fluctuations tend r together in time, stock price returns were de- y models of volatility (standard deviation of re- .anging in time [7,8]. This effect is captured in :s models, in which the volatility at a given time on the magnitude of previous returns [9,10]. It actively investigated how the stochastic prop

sell orders (order imbalance), which acts as an external force. We study the dependence of stock price changes on order imbalance empirically along the lines of [21–23] for a major American stock and find that it agrees well with our model.

Model calculation: The observable quantity we are interested in is the logarithmic stock price changes within a time interval Δt

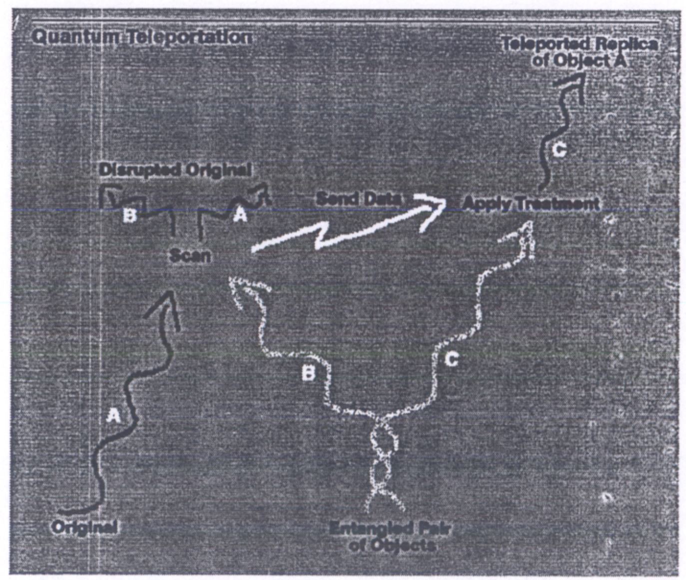
$$G_{\Delta t}(t) = \ln S(t) - \ln S(t - \Delta t) \ , \qquad (1)$$

where $S(t)$ is the price of a given stock at time t. Transaction prices at a stock exchange lie usually in a finite interval between the bid price (the price a trader offers to pay for a stock) and the ask price (the price at which a dealer is willing to buy the stock). In addition, the historical prices studied take only discrete (tick) values

The Future of Spin

– Quantum information is data that is sent through single atoms, photons, and other particles or groups of particles that obey the strange laws of quantum mechanics. Related topics: Quantum Density Matrix, Mutual Information and Conditional Entropy, Galois Fields, and Quantum Coding Theory.

– Quantum teleportation, though once thought only the work of Star Trek science fiction writers, is the ability of information to disintegrate in one place while a perfect replica appears somewhere else.



– Quantum computation uses the uncertainties of quantum mechanics to its advantage. A successful quantum computer would be exponentially faster than a classical computer.

A WORLD WITHOUT SPIN WOULD COLLAPSE

SO KEEP IT UP (OR DOWN, AS YOU WISH)

THANK YOU