Parity Violation searches at RHIC satisfy all my Criteria for The Maximum Discovery Potential :

- Look where most theorists predict that nothing will be found.
- Look in a channel where the known rates from conventional processes are small, since low background implies high sensitivity for something new.
- Be the first to explore a new domain—something that has never been measured by anybody else.

In the late 1960's, I thought that the dilepton channel satisfied all of these same criteria... In the intervening quarter century, this channel was indeed the major source of discovery. I feel that parity violation searches offer the same discovery potential today!

PHENIX $W^{\pm} \rightarrow e^{\pm} + X$ 16000 Events

$\delta A_L \leq 1.2\%$

STAR **better**—*in principle!*

Leading hadron (π^0) or photon or ...

$\delta A_{LL}^{PV} \sim 0.1\%$ to 1%

JETS even better $\delta A_{LL} \ll 0.1\%$

WHY Parity Violation ?

There are very few measurements of, or searches for, Parity Violation in hadron reactions.

AT HIGH ENERGIES THIS FIELD IS TOTALLY UNEXPLORED

Large "conventional" effects are predicted at RHIC energies due to the direct production of the Weak Bosons $W^{\pm}$ and Z^0.
The standard model effects at RHIC are ~ 1
We use the parity-violating asymmetry in these channels to measure flavor identified spin-structure functions.

ARE THERE NEW EFFECTS ?

It is not unreasonable to hope that the systematic search for Parity Violation might reveal new physics!

Almost any model for NEW PHYSICS violates parity
e.g Composite models
since any new mass scale $\Lambda \geq M_W$

How do we know that direct–γ production isn't 30% parity violating?
Nobody ever looked—
In the "standard" model, no parity violation is expected—
BUT
"The absence of evidence is not the evidence of absence."
Maurice Goldhaber—*quoting astronomers.*

QCD

Cross Section in p-p collisions c.m. energy $\sqrt{s}$

The overall p-p reaction cross section
is the sum over constituent reactions

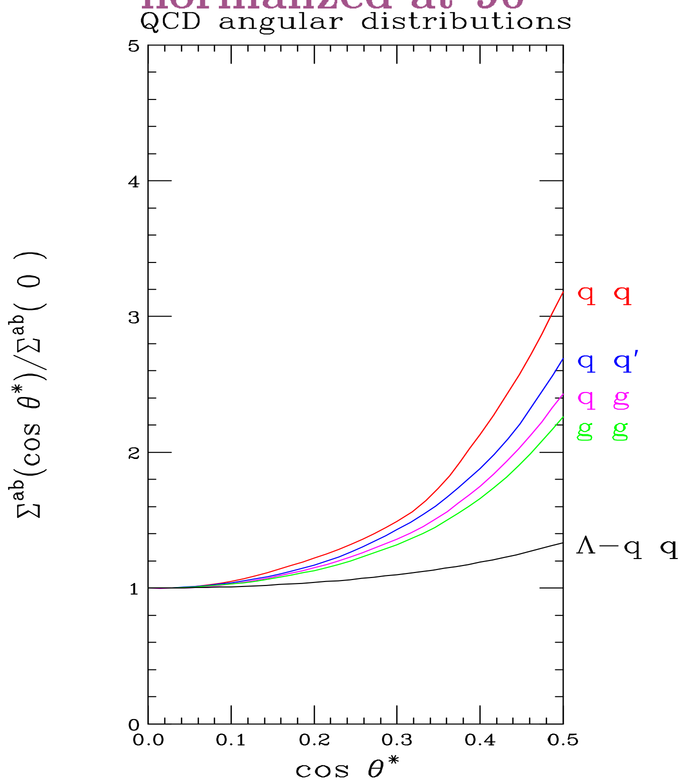
$$a + b \rightarrow c + d$$

$a(x_1)$, $b(x_2)$, are structure functions, the differential probabilities for constituents a and b to carry momentum fractions x_1 and x_2 of their respective protons, e.g. $u(x_1)$,

$$\frac{d^3\sigma}{dx_1 dx_2 d\cos\theta^*} = \frac{1}{s}\sum_{ab} a(x_1)b(x_2)\frac{\pi\alpha_s^2(Q^2)}{2x_1x_2}\Sigma^{ab}(\cos\theta^*)$$

$\Sigma^{ab}(\cos\theta^*)$, the characteristic subprocess angular distributions and $\alpha_s(Q^2) = \frac{12\pi}{25}\ln(Q^2/\Lambda^2)$ are predicted by QCD

QCD Subprocess predictions $\Sigma^{ab}(\cos\theta^*)$ normalized at 90°



1983—Substructure Model of Eichten, Lane, Peskin is Parity Violating

1995-6—CDF reports possible "Substructure" Jet Cross section deviates from 'QCD' at large p_T

The effect looks exactly like 1983 figure of σ_{unpol} from calculations in BNL Memos, Newsletters done by Frank Paige (and me)!

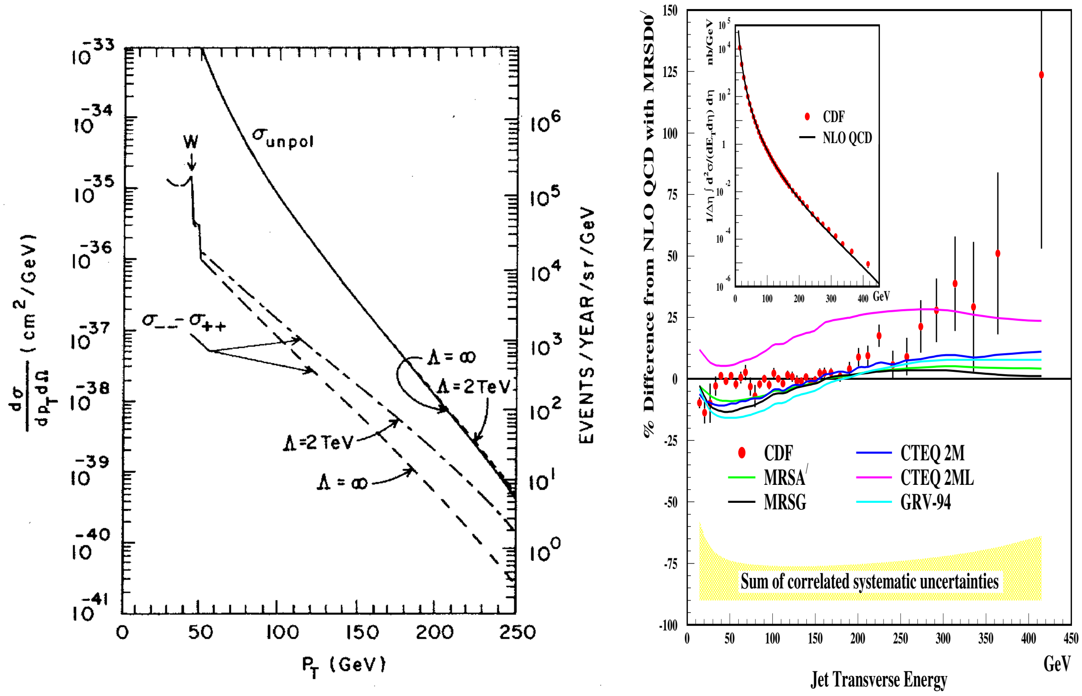


Figure 1: a) Prediction from 1983 for the effect of Quark Substructure on inclusive jet cross section at 800 GeV c.m. energy with and without Parity Violation capability. b) 1995-6 CDF Inclusive jet cross section and ratio to NLO QCD.

At PSU in 1990, I stated "Without the PVA handle, the CDF detector is limited to searching for substructure by deviations of jet production from QCD at large values of p_T... the advantage of the PVA signature is that **it is a clear indication of new physics**—qualitative not quantitative!

The CDF measurement above is a case in point: If the "% Difference from NLO QCD" were "% Parity Violation", the parity-violating signature would be unambiguous evidence of new physics. However, serious people say that CDF just used the **wrong gluon structure function!**

There are Several Issues to Discuss

- Is CDF 'substructure' effect $\Lambda \simeq 1.4$ TeV ruled out by other measurements? For instance the limit from Parity Violation in atoms is ~ 25 TeV, but this is for an $e-p$ interaction, not a $p-p$ $(q-q)$ interaction.

- Is the gluon structure function (non-polarized) well known? I looked up the paper critical of CDF, and I present their 'even better than new' gluon structure function below, together with the previous 'standard' by Aurenche, et al. **Clearly we must also measure the unpolarized Gluon Structure Function at RHIC!**

6142 HUSTON, KOVACS, KUHLMANN, LAI, OWENS, AND TUNG 51

51 GLOBAL QCD STUDY OF DIRECT PHOTON PRODUCTION 6143

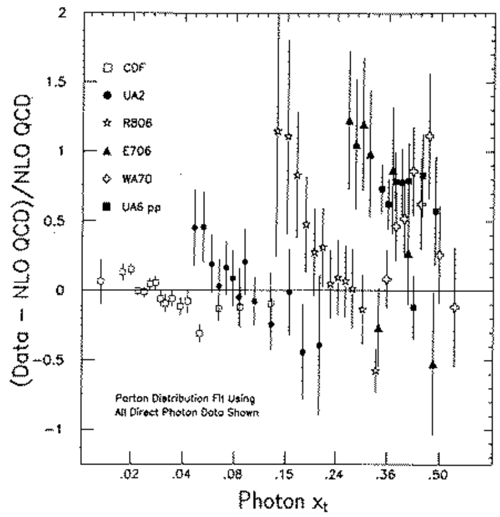


FIG. 5. Compilation of direct photon experiments compared to a NLO QCD prediction using parton distributions fit using all the data shown (see text).

AURENCHE, BAIER, FONTANNAZ, OWENS, AND WERLEN

39 GLUON CONTENT OF THE NUCLEON PROBED WITH REAL . . . 3283

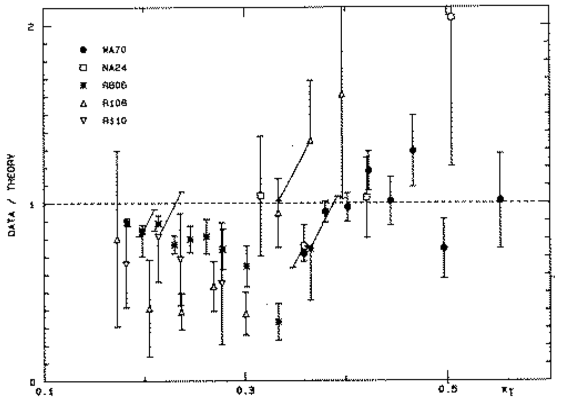


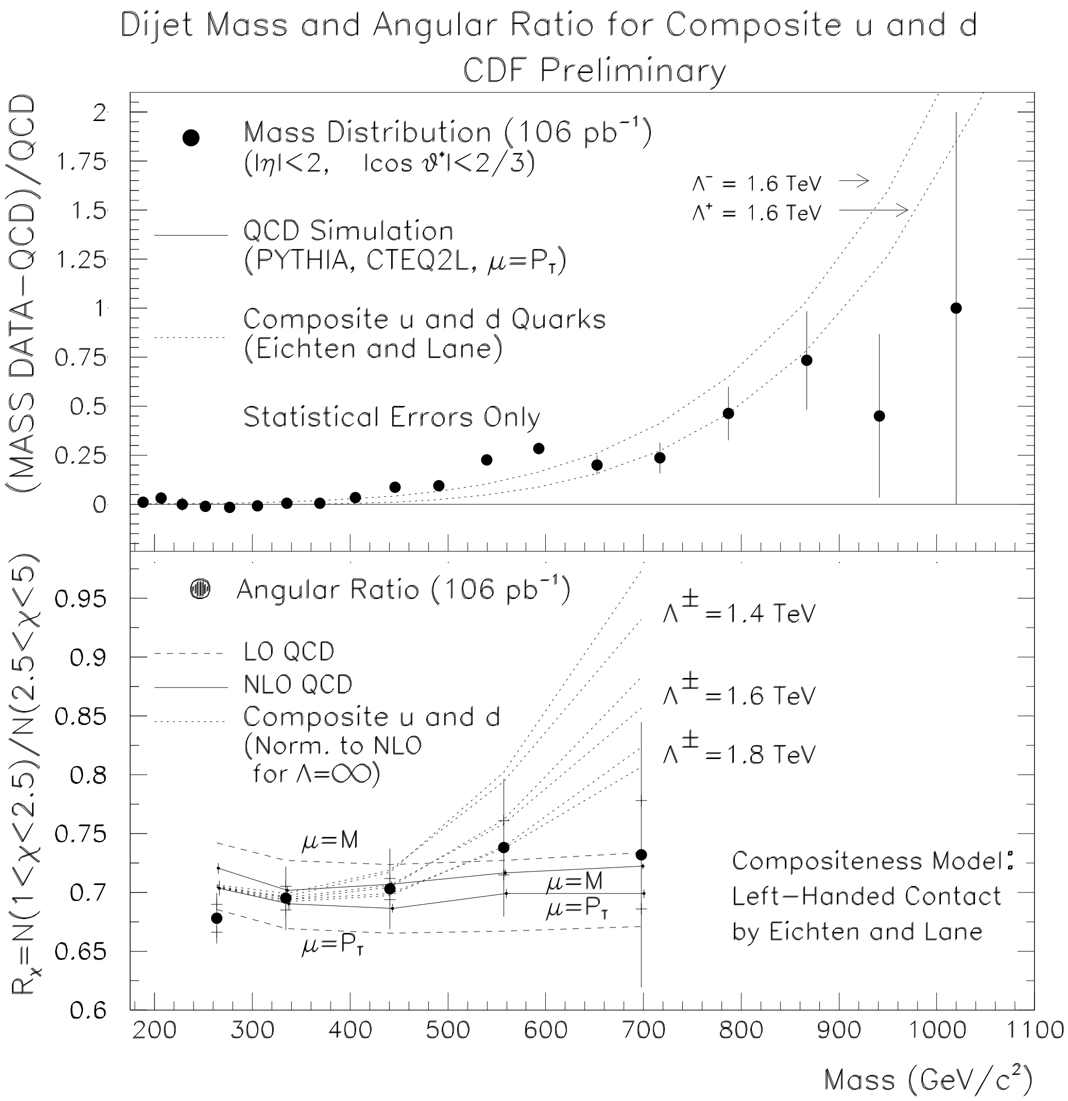
FIG. 10. Ratio data/theory for fixed-target (Refs. 10 and 11) and ISR (Refs. 25–27) $pp \to \gamma X$ experiments.

Is there a 'Robust' Substructure limit from CDF?

The constituent angular distribution can be measured and can be used to distinguish the characteristic QCD 'Rutherford Scattering' $\Sigma^{qq}(\cos\theta^*)$ from the relatively flat 'substructure' effect (see p.3). This measurement is performed with two 'back-to-back' jets or leading particles from jets:

$$(y_{\rm Jet1}+y_{\rm Jet2})/2=\hat{y}\cong 0 \qquad \cot\theta^*=\sinh|(y_{\rm Jet1}-y_{\rm Jet2})/2|$$

CDF uses the ratio in two regions of $|\cos\theta^*|$ using a transformed (unnecessarily) variable χ; D0 measures the χ distribution:



Sensitivity to New Physics—e.g. Λ at RHIC

The parity violation effect from the Eichten, Lane, Peskin Model can be easily estimated directly from the matrix elements (and the spin structure function) and just depends on x and $\cos\theta^*$. However, for sensitivity estimates, the cross-section must be calculated, which is more challenging and requires professionals. For the latest sensitivity estimate, see P. Taxil & J. M. Virey, Phys. Rev. **D 55**, 4480 (1997).

From Snowmass '82, 1983 Memos and PSU Workshop

$$\sigma = \sigma_{QCD} + \sigma_\Lambda = \sigma_{QCD} + \frac{1}{4}(\sigma_\Lambda^{--} + \sigma_\Lambda^{++} + \sigma_\Lambda^{-+} + \sigma_\Lambda^{+-}) = \sigma_{QCD} + \frac{1}{4}\sigma_\Lambda^{--}$$

$$A_{LL}^{PV} = \frac{\sigma^{--} - \sigma^{++}}{\sigma^{--} + \sigma^{++}} \cong \frac{\sigma_\Lambda^{--}}{2\sigma_{QCD}} = \frac{2\sigma_\Lambda}{\sigma_{QCD}}$$

At high x, where qq (uu) dominates

$$A_{LL}^{PV} \simeq 2\frac{\Delta q(x)}{q(x)}\frac{\Sigma_\Lambda^{qq}(\cos\theta^*)}{\Sigma_{QCD}^{qq}(\cos\theta^*)}$$

The effect depends on x and $\cos\theta^*$ with a factor of $-\eta\hat{s}/\alpha_s\Lambda^2$, $\eta = \pm 1$.
The effect is maximum at $90°$, $\cos\theta^* = 0$, $\hat{s} = -2\hat{t} = 4p_T^2$

$$A_{LL}^{PV}(\cos\theta^* = 0) \cong 2\,\frac{\Delta q(x)}{q(x)}\frac{24}{11}\frac{\eta\hat{t}}{\alpha_s\Lambda^2}(1 + \frac{21}{32}\frac{\eta\hat{t}}{\alpha_s\Lambda^2})$$