DIS 97
CHICAGO 14-18 AF

ACCESSING THE GLUON POLARIZATION $\Delta G/G$ VIA HIGH P_T CORRELATED HADRON PAIRS (h^+h^- & K^+K^-)

by

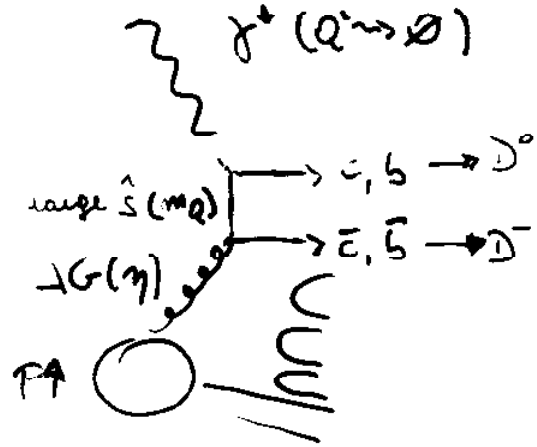
ALESSANDRO BRAVAR
UNIVERSITY MAINZ

POLARIZED $\ell\uparrow$ $p\uparrow$ SCATTERING

DIS & $Q^2 \to \emptyset$ PHOTO-PRODUCTION LIMIT

PHOTON-GLUON FUSION

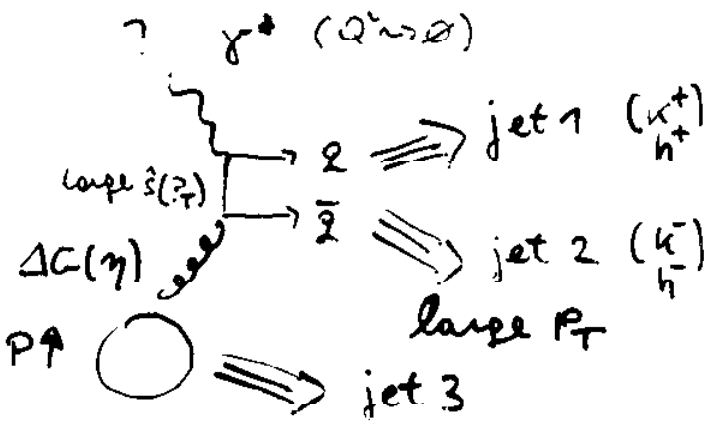
- HEAVY FLAVORS (c, b)

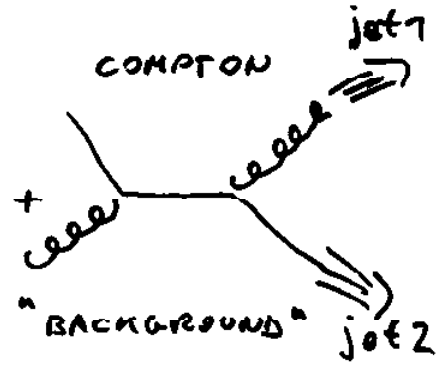


$$A_{LL} \sim \langle a_{LL}^{PGF} \rangle \cdot \langle \frac{\Delta G}{G} \rangle$$

$$\delta \langle \frac{\Delta G}{G} \rangle \sim \langle a_{LL}^{PGF} \rangle^{-1} \cdot \delta A_{LL}$$

- DI-JETS & CORR. HIGH P_T HADRONS





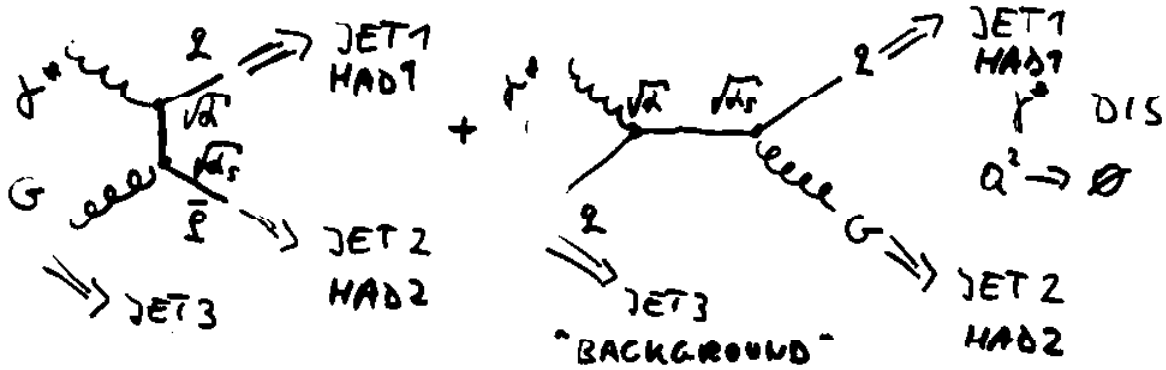
$$W = \frac{\sigma^{PGF}}{\sigma^{TOT}}$$

$$A_{LL} \sim \langle a_{LL}^{PGF} \rangle \cdot \langle \frac{\Delta G}{G} \rangle \cdot W + \langle a_{LL}^{COMPT} \rangle \cdot \langle \frac{\Delta \mu}{\mu} \rangle \cdot (1-W)$$

$\to$ "subtract" COMPTON : ADDS ADDITIONAL UNCERTAINTY ON $\langle \frac{\Delta G}{G} \rangle$

G and ΔG from DI-JETS and HIGH P_T CORRELATED HADRONS

L.O. (α_s) QCD DIAGRAMS FOR 2 JET PRODUCTIO



$$\Delta\sigma^{HH} = \int_{PH.S} \Delta q(x)\, \Delta\hat{\sigma}^{L.O.}\, \cancel{D_q^{HH}}^{=\emptyset} +$$

$$\Delta G(\eta)\, \Delta\hat{\sigma}^{PGF} \left[D_{q\bar{q}}^{HH} + 1 \leftrightarrow 2 \right] +$$

$$\Delta q(\eta)\, \Delta\hat{\sigma}^{com} \left[D_{qG}^{HH} + 1 \leftrightarrow 2 \right]$$

SCALE ~ $\sum p_T^2$ (~ 10 GeV^2 for high p_T had)

η - MOMENTUM FRACTION

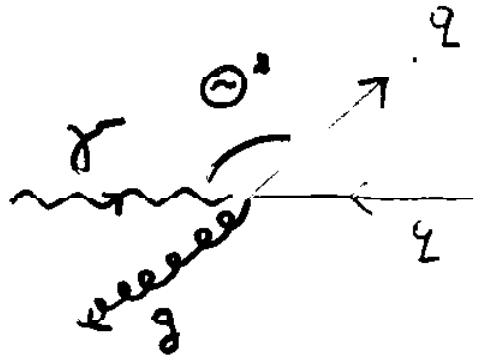
q MOSTLY u QUARKS (charge 2 $\eta \sim 0.1$)

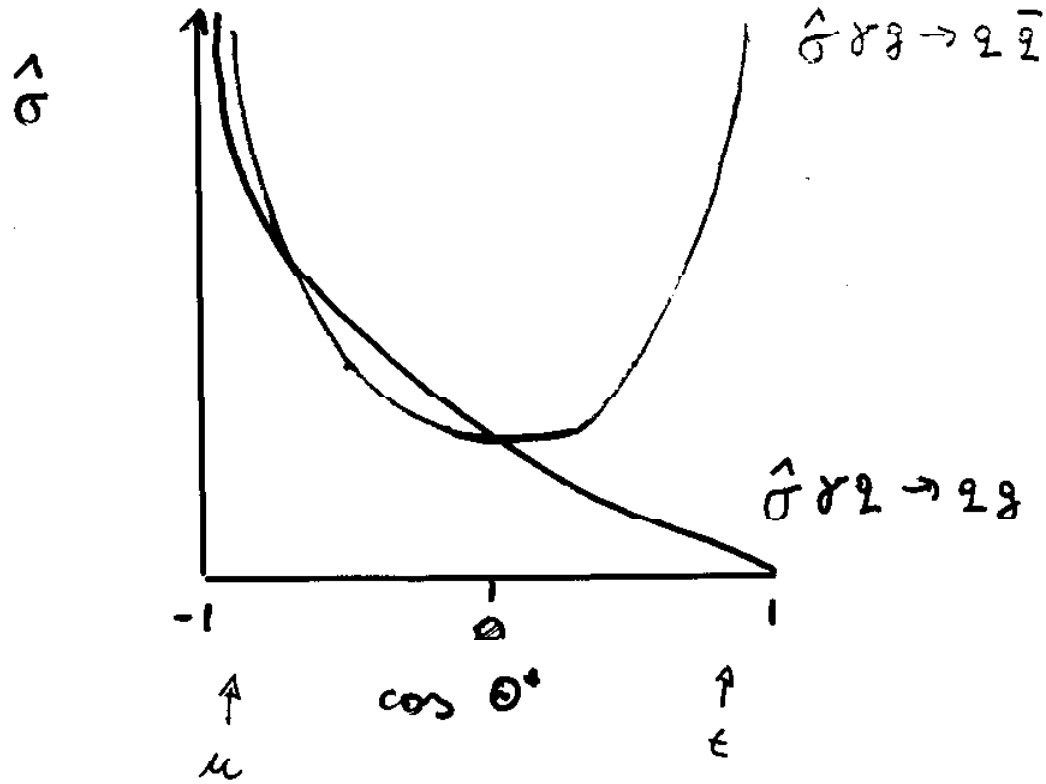
$$A_{LL}^{HH} = \frac{\Delta\sigma^{HH}}{\sigma^{HH}} \sim \langle a_{LL}^{PGF} \rangle \langle \frac{\Delta G}{G} \rangle \frac{\sigma^{PGF}}{\sigma^{TOT}} +$$

$$\langle a_{LL}^{com} \rangle \langle \frac{\Delta u}{u} \rangle \frac{\sigma^{com}}{\sigma^{TOT}}$$

TO EXTRACT (Δ)G MUST "SUBTRACT" COMPTON BK

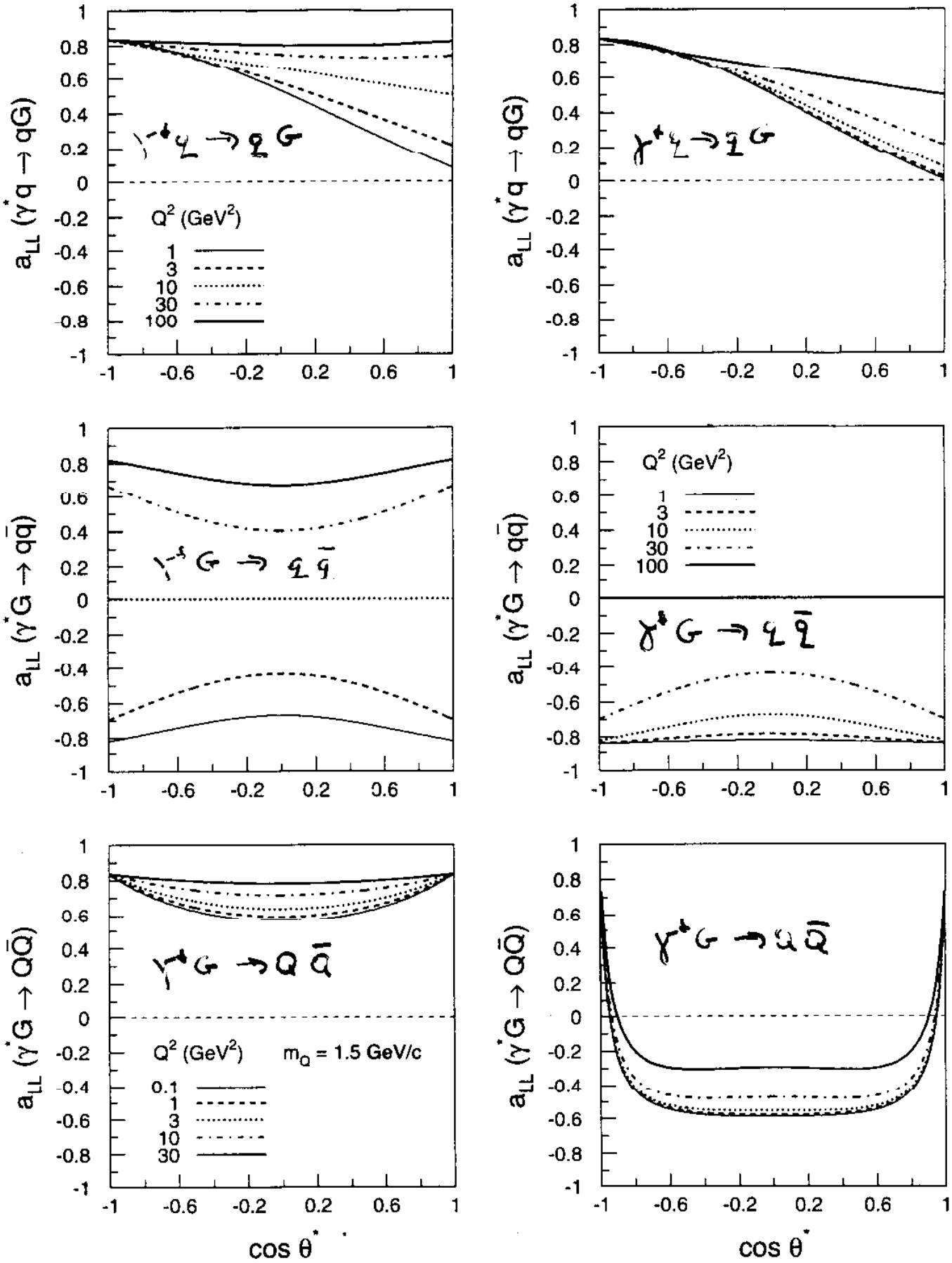
$$\frac{\sigma^{PGF}}{\sigma^{com}} = f(\eta, Q^2) \propto \frac{G(\eta, Q^2)}{u(\eta, Q^2)}$$


q
θ*
γ
q
g


σ̂
σ̂ γg → q q̄
σ̂ γq → qg
-1
0
1
cos θ*
u
t

SPIN ASYMMETRY $a_{LL} = \Delta\sigma / \sigma$ $Q^2 \neq 0$

$\hat{s}$ = 10 GeV^2, y = 0.7 $\bar{\delta} = 0.84$ $\hat{s}$ = 100 GeV^2, y = 0.7



BASIC CROSS SECTION ASYMMETRIES

$$\hat{a}_{LL} = \frac{\Delta\hat{\sigma}}{\hat{\sigma}} \quad (L.O.)$$

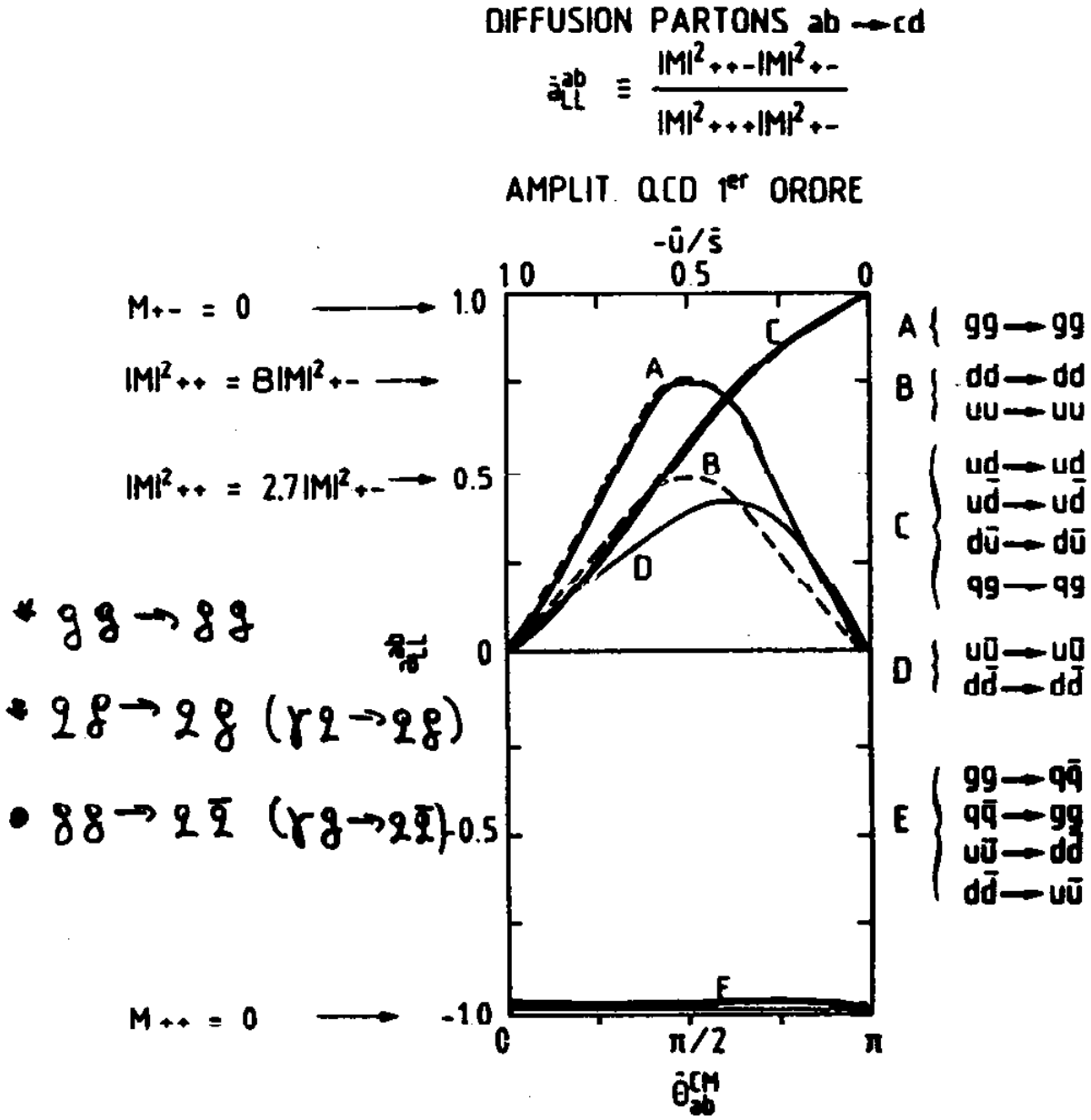
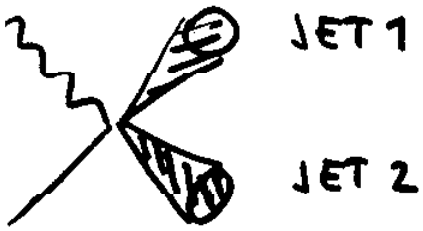
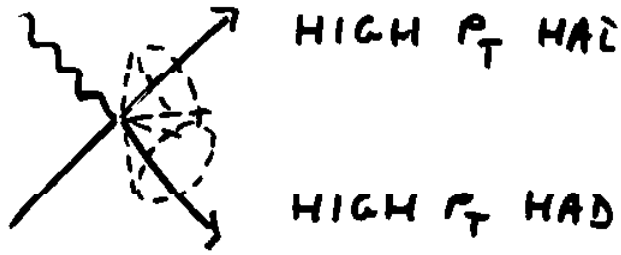


Fig. 5.10. The basic Born asymmetries of QCD perturbation.

TAGGING THE PGF



COLLIDER
LARGE $\sqrt{s}$



FIX TARGET
LOWER $\sqrt{s}$

COLL: LARGE $\sqrt{\hat{s}}$ → (VERY) HIGH P_T ($P_T > 5$ GeV)
JET ALGORITHM → JETS.

F.T.: LOWER $\sqrt{\hat{s}}$
EFFECTS α_s DIAGRAMS CLEARLY VISIBLE
[EMC, E665

→ • CHARACTERISTIC EVENT SHAPES
→ • BROADER ANGULAR DISTRIBUTIONS
→ • LARGE $\Sigma|P_T|$

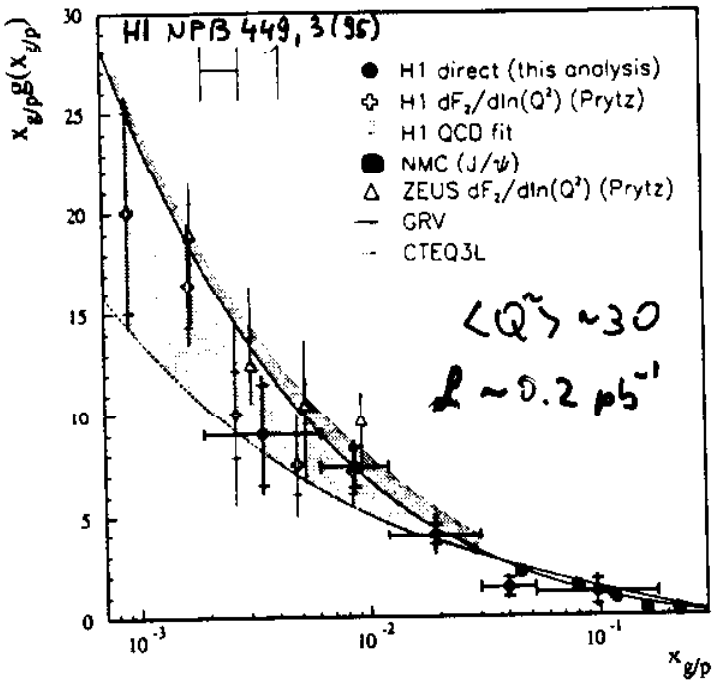
→ JET TAGGING VIA HIGH P_T HADRONS
2 HIGH P_T^* PARTONS IN C.M. →
2 HIGH P_T HADRONS IN LAB. ($P_T^* > P_T$!

→ LOOK FOR H1 WITH $P_T > P_0$ AND
H2 ($P_T > P_0$) OPPOSITE IN AZIMUT
ONLY HARD PART SURVIVE FOR $P_0 \geq 1$-1.5 G
[P_0 FROM NUMERICAL ANALYSIS AND M&C]

→ CORRELATED HIGH P_T HADRON PAIR

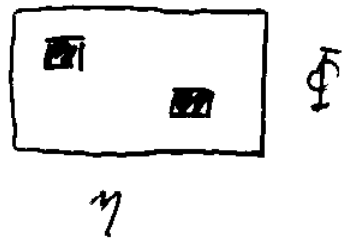
MEASUREMENT OF G

HERA H1 $\sqrt{s} = 300$



DIRECT MEASUREM

i.e. JETS "SEEN" IN DETECTOR

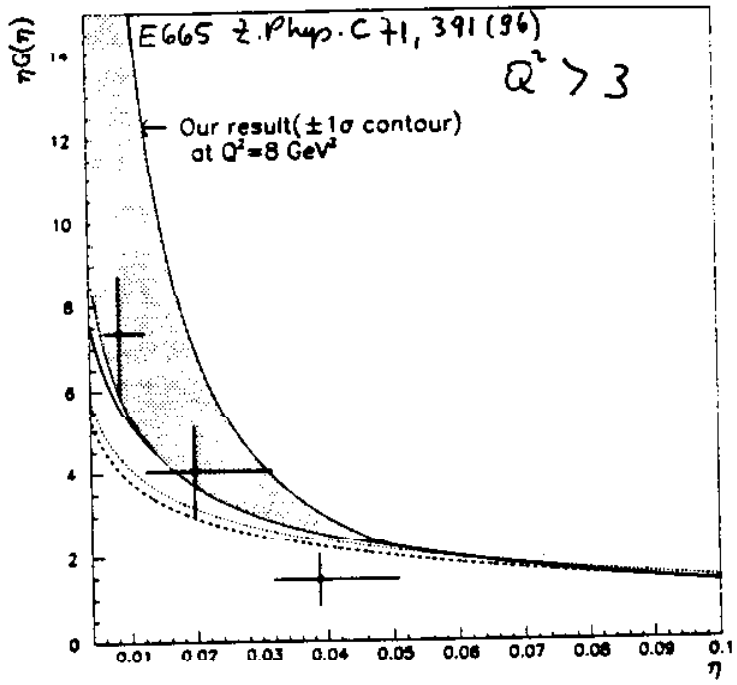


$R = \sqrt{\Delta\eta\,\Delta\Phi} < 1$

CONE ALGORITHM

$m_{ij}^2 < y_{cut} \cdot W^2$

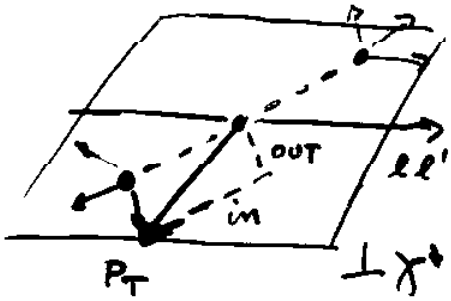
FT E-665 FERMILAB $\sqrt{s} = 30$



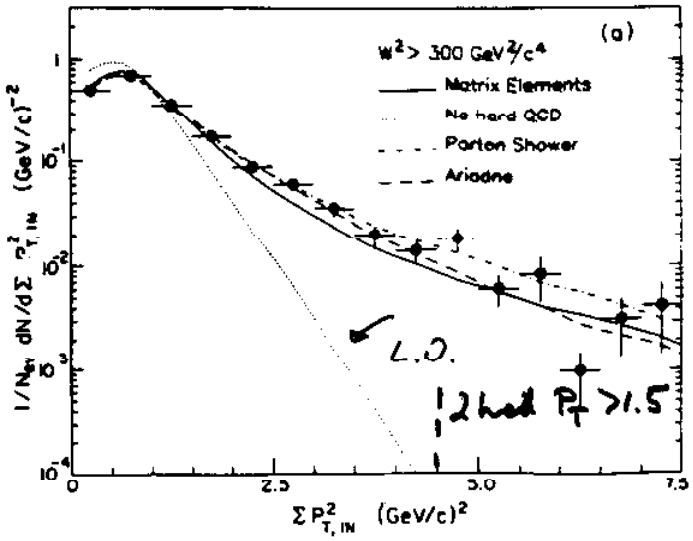
FROM EVENT SHAPE DISTRIBUTIONS

MORE DIFFICULT

Σ TRANSVERSE MOMENTUM $\perp \gamma^*$

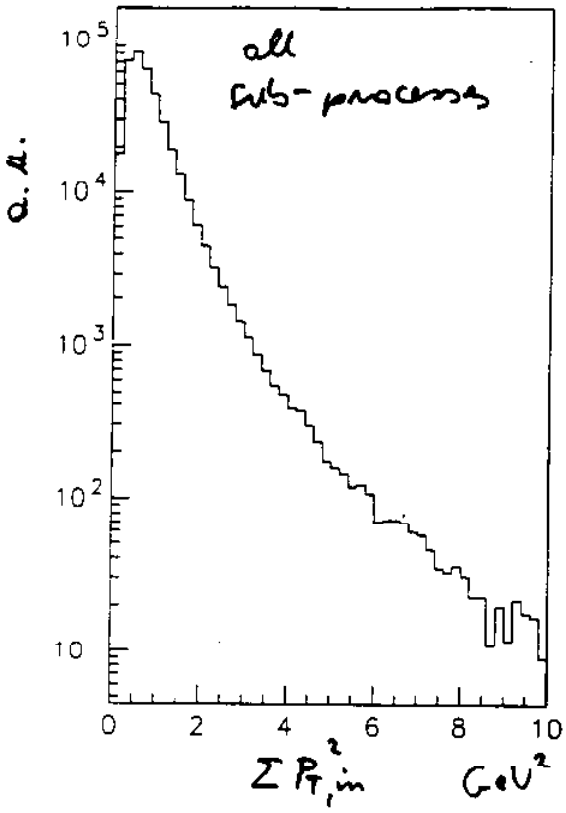


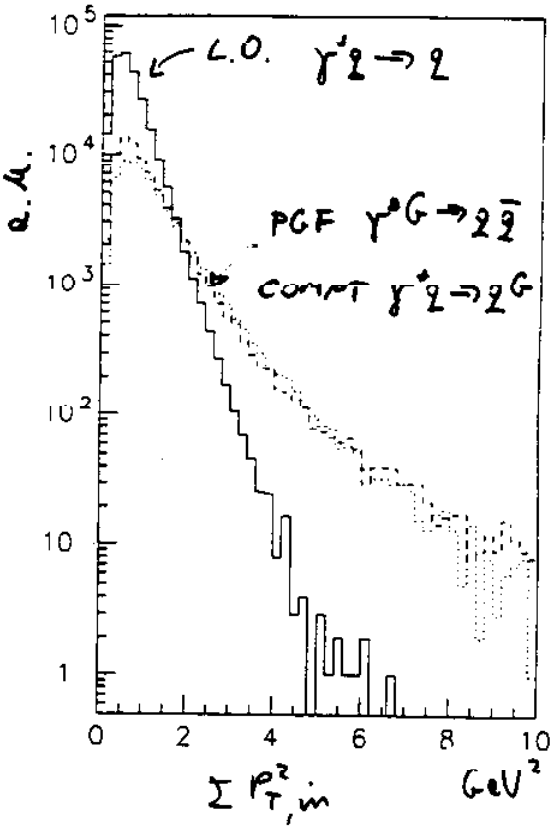
E-665 (FNAL) $E_\mu \sim 500$ GeV



OUR M&C - LEPTO 6.5 + JETSET 7.4

$E_\mu = 200$ GeV; $0.5 \leq y \leq 0.9$; $Q^2 \geq 4$ MRSA' (GRV)

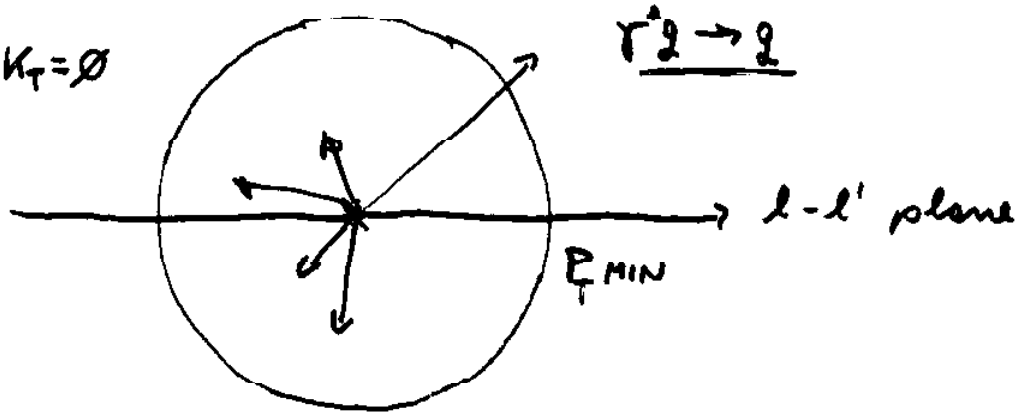




TRANSVERSE PLANE i.e. $\perp \gamma^*$

- $K_T = \emptyset$

$\gamma^* q \to q$



$$R^h(P_{T\,MIN}) = \frac{P_T^h > P_{T\,MIN}}{ALL\ P_T} \sim e^{-\frac{P_{T\,MIN}^2}{\langle P_F^2 \rangle}}$$

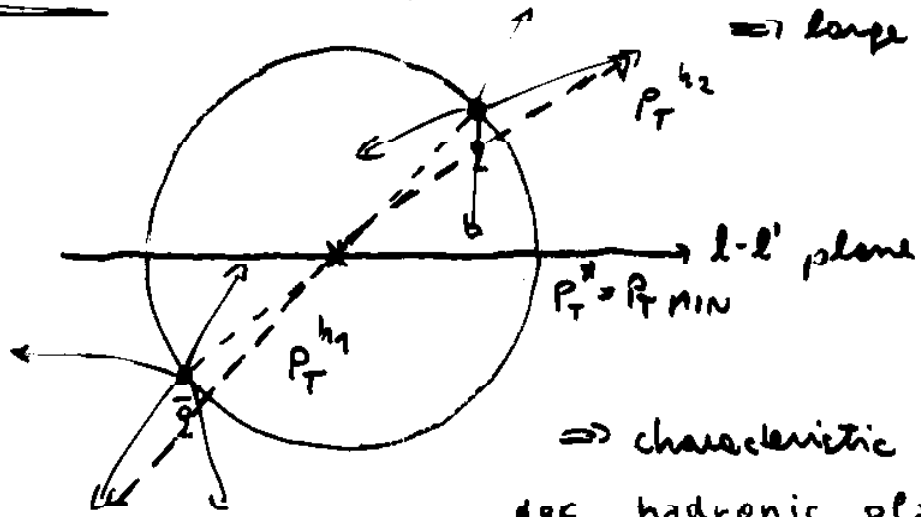
$P_F \sim 0.36$ GeV
$P_T > 1$ GeV
$R < 10^{-3}$

$$D_q^{h_1 h_2}(P_{T1}, P_{T2} > P_{T\,MIN}) < D_q^h(P_T > P_{T\,MIN})$$

$K_T \neq \emptyset$

$$P_T^h = P_{T\,MIN} + z K_T \qquad \langle z K_T \rangle \sim 0.2 \cdot 0.44 \sim 0.1 \text{ Ge}$$

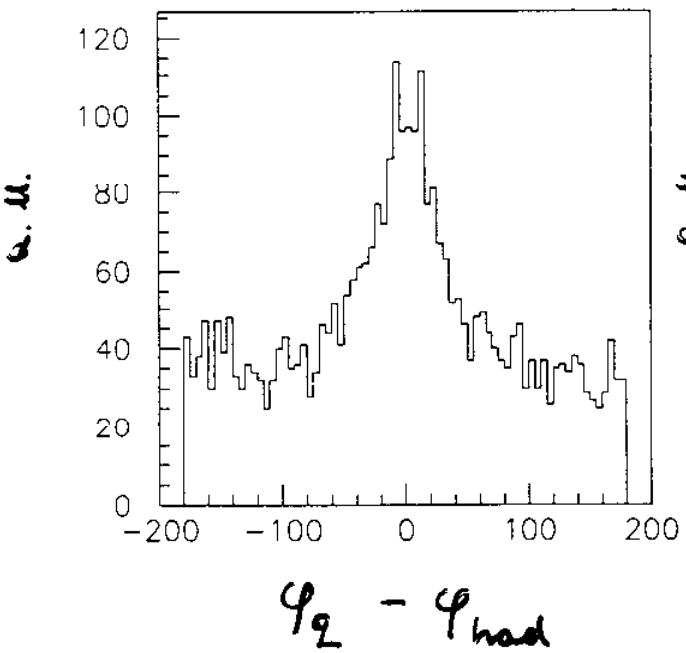
- $\gamma^* g \to q\bar{q}$ $(\gamma^* q \to q g)$ large P_T^* i.e 90° c.m.
$\Rightarrow$ large $\hat{s}$



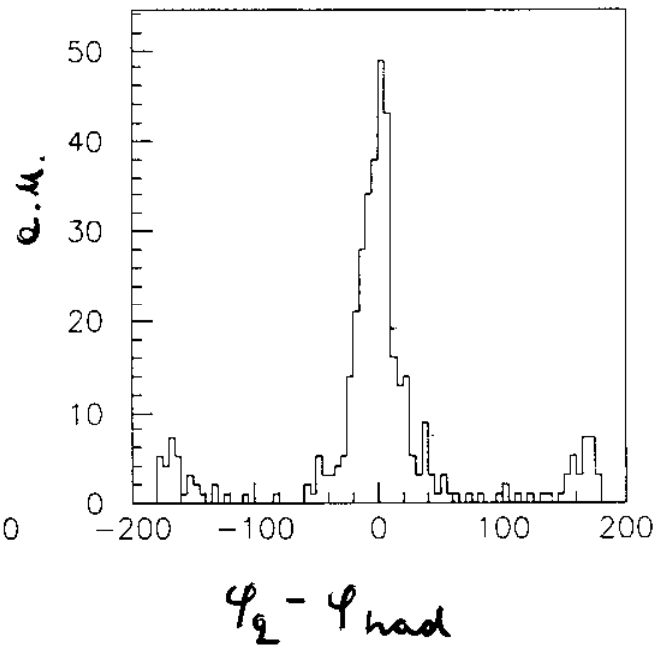
$\Rightarrow$ characteristic event sha
def. hadronic plane

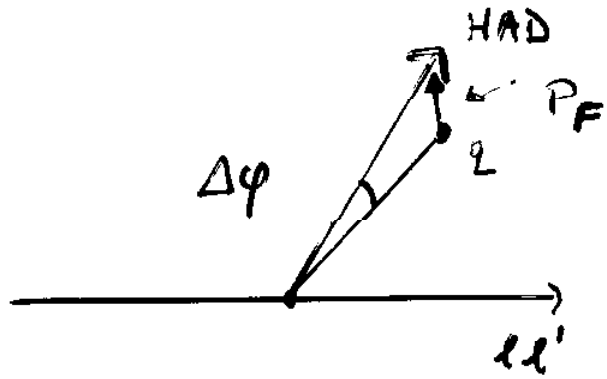
FRAGMENTATION

PGE : "all" events

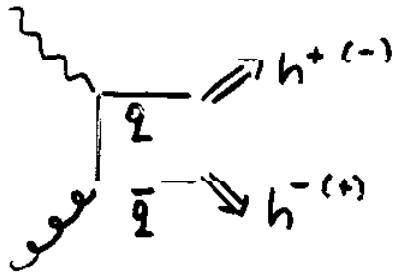


PGE: $p_T^{\pm} > 1$, $y_p^{\pm} > 0$, $m > 3$

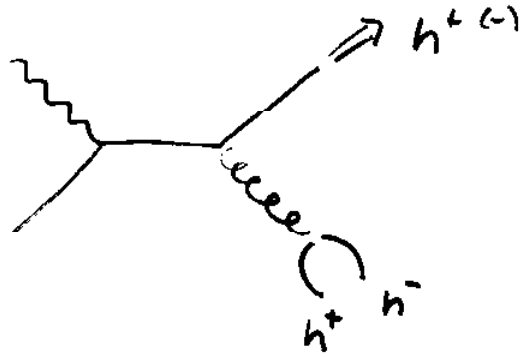




SELECTING THE PGF



OPPOSITE CH.



EQUAL CH.

ASK FOR

- 2 high p_T hadrons ($p_T > 1.0 - 1.5$; $m(+,-) > 2-3$)
- opposite charge:
  q & $\bar{q}$ fragment pref. to opposite ch. hadrons
  $2N^{+-} - N^{++} - N^{--}$ would "subtract" compton
- opposite in asimuth : $\Delta\varphi = 180°$ (p_T cut)
- p_T balanced : $\Delta p_T = |p_T^+ - p_T^-| < a$
- fast hadrons: $x_F^{\pm} > 0$
- invariant mass $m(h^+h^-) > M$ to avoid cut-offs in M.E.

FURTHER SUPRESSION OF COMPTON "BKG"
strangeness production supressed by 3-5 in hadr

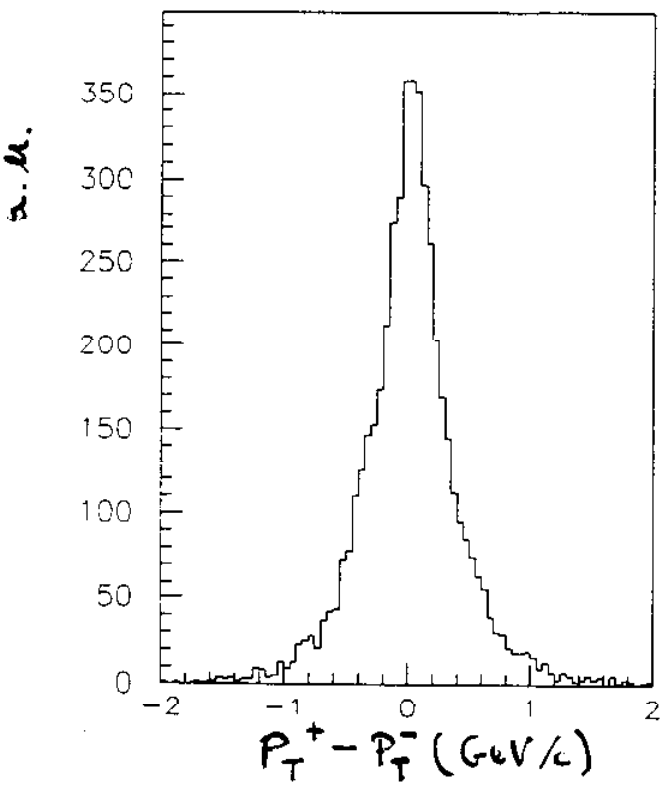
$\Rightarrow$ LOOK FOR 2 HIGH p_T KAONS

$s\bar{s}$(PGF) $\rightarrow K^+K^-$ LIKELY

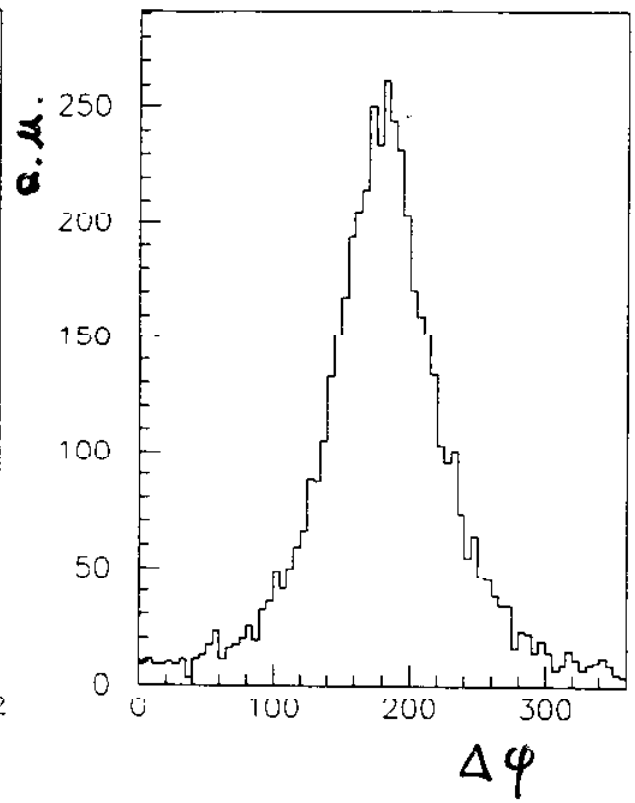
cG(COM) $\rightarrow K^+K^-$ UNLIKELY

'SELECTED' EVENTS

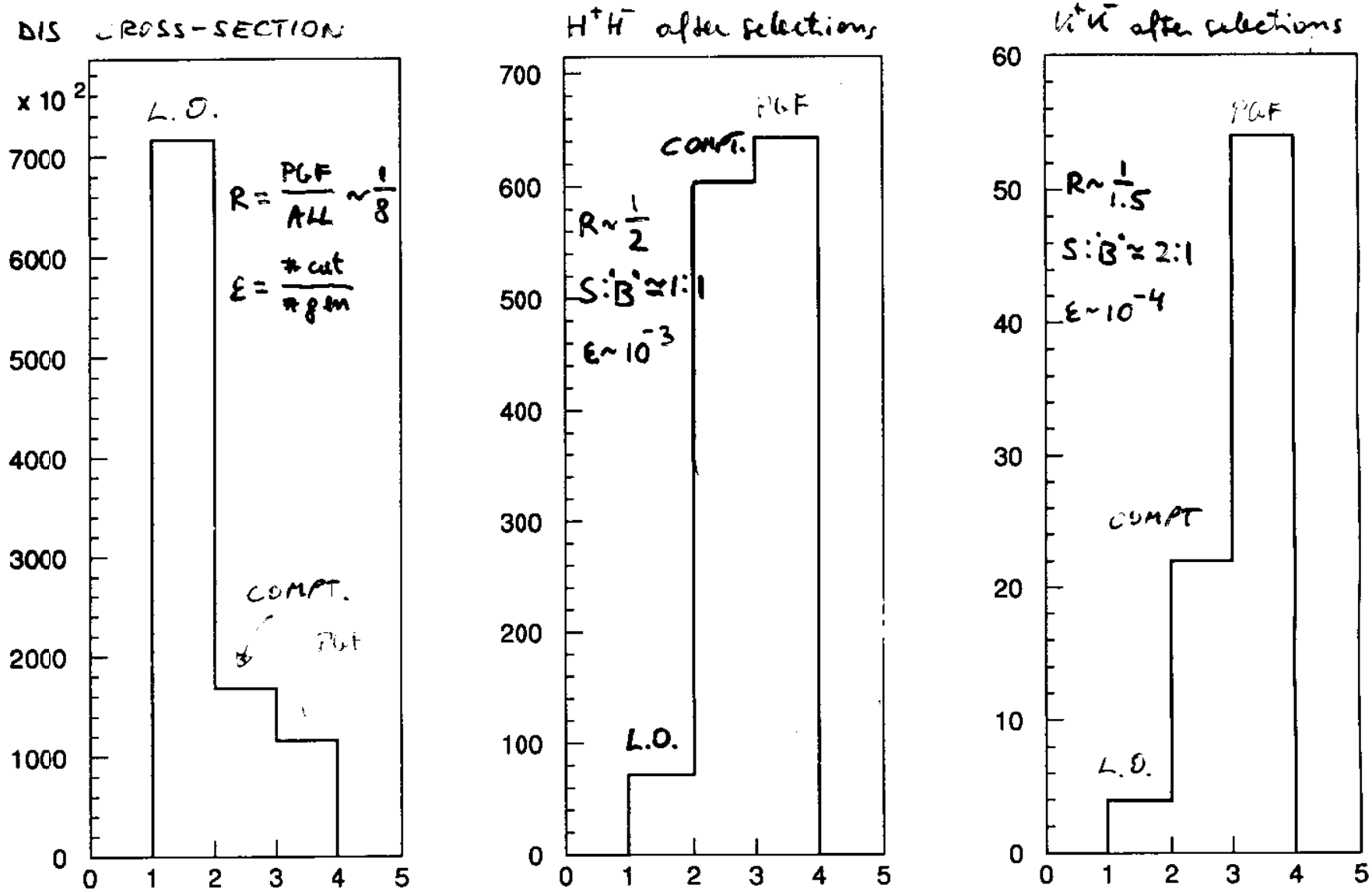
P_T MOMENTUM BALANCE



$\Delta\varphi = \varphi^+ - \varphi^-$



ENHANCING THE PHOTO-GLUON FUSION DIAGRAM

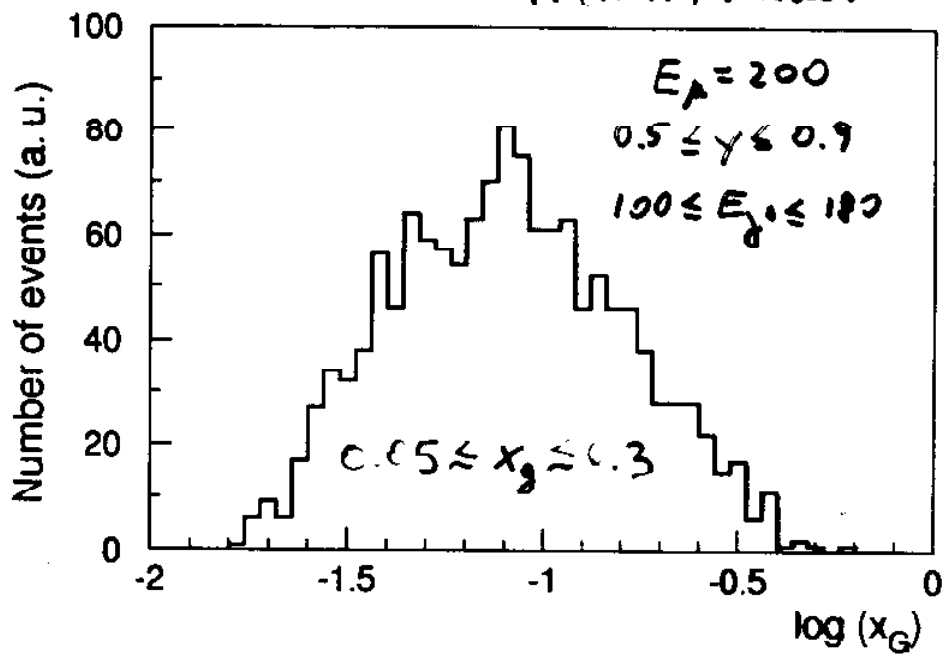


CUTS: $p_T^{\pm} > 1$ GeV, $x_F^{\pm} > 0$, $m(+,-) > 3$ GeV (using GRV 94 LO

GLUON DISTRIBUTION (GRV94LO)

FOR H^+H^- PAIR $P_T > 1$ GeV

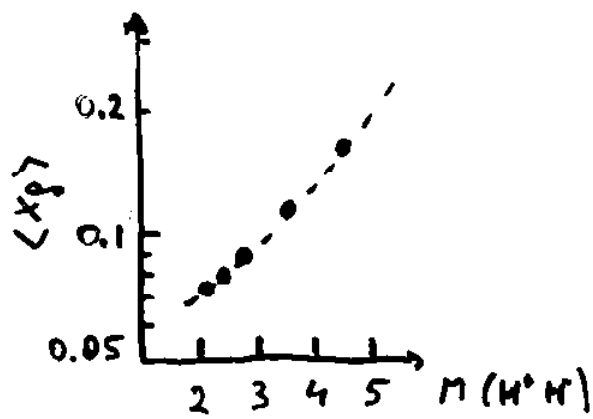
$M(H^+H^-) > 2$ GeV



DIFFERENT GLUONS GIVE SAME DISTRIBUTIONS

ALSO $R = \sigma^{PGP}/\sigma^{COMPT}$ STABLE

CORRELATION $\langle x_g \rangle$ vs. $M(H^+H^-)$



$x_g \propto \hat{s} \propto M^2$

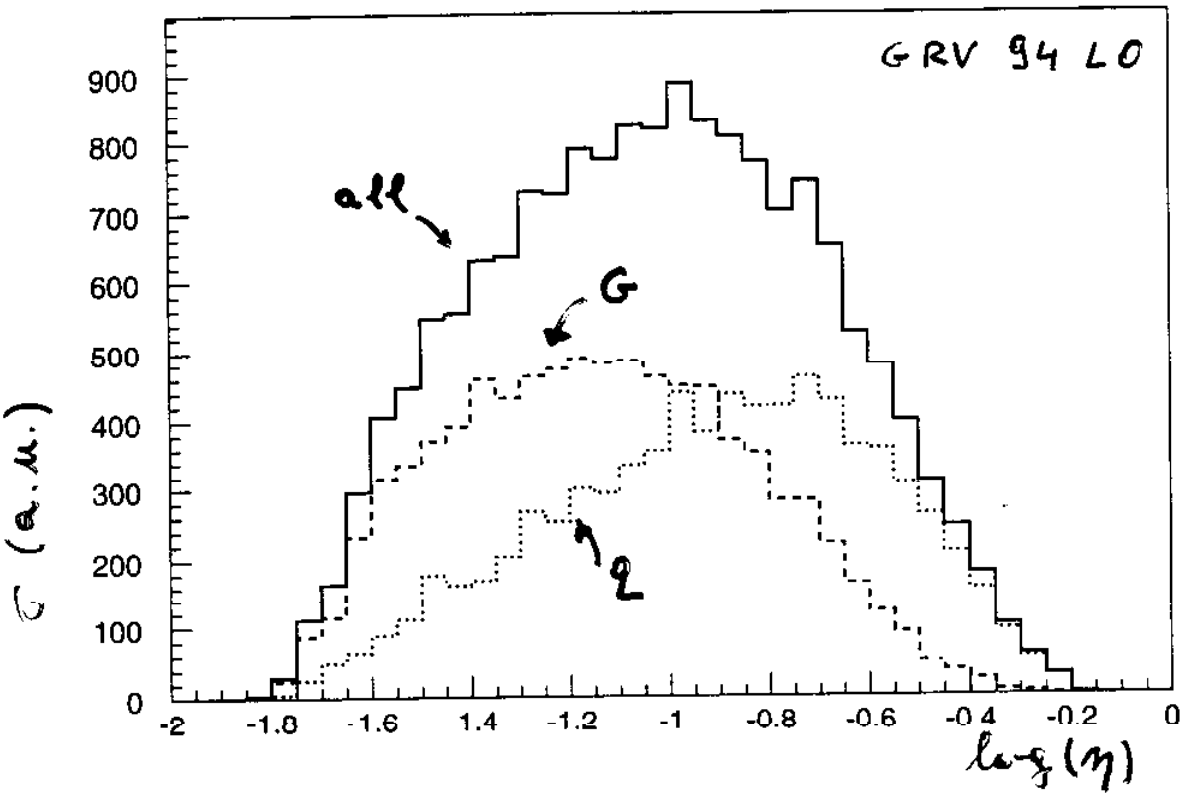
USE ALL EVENT INFO (i.e. PART

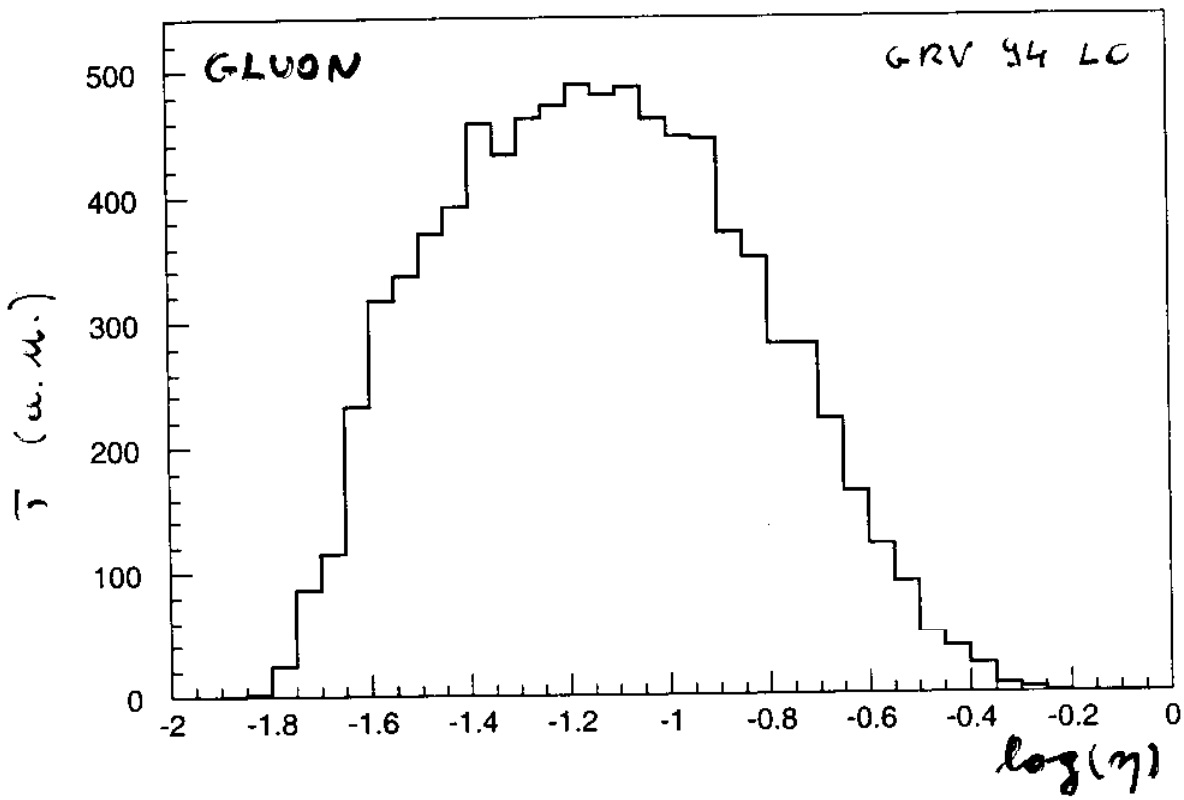
$\Rightarrow$ BETTER CORRELATION

BIN IN $M(H^+H^-)$ $\rightarrow$ COVER DIFFERENT x_g INTE

$H^+ H^-$ PAIR GLUON DISTRIBUTION

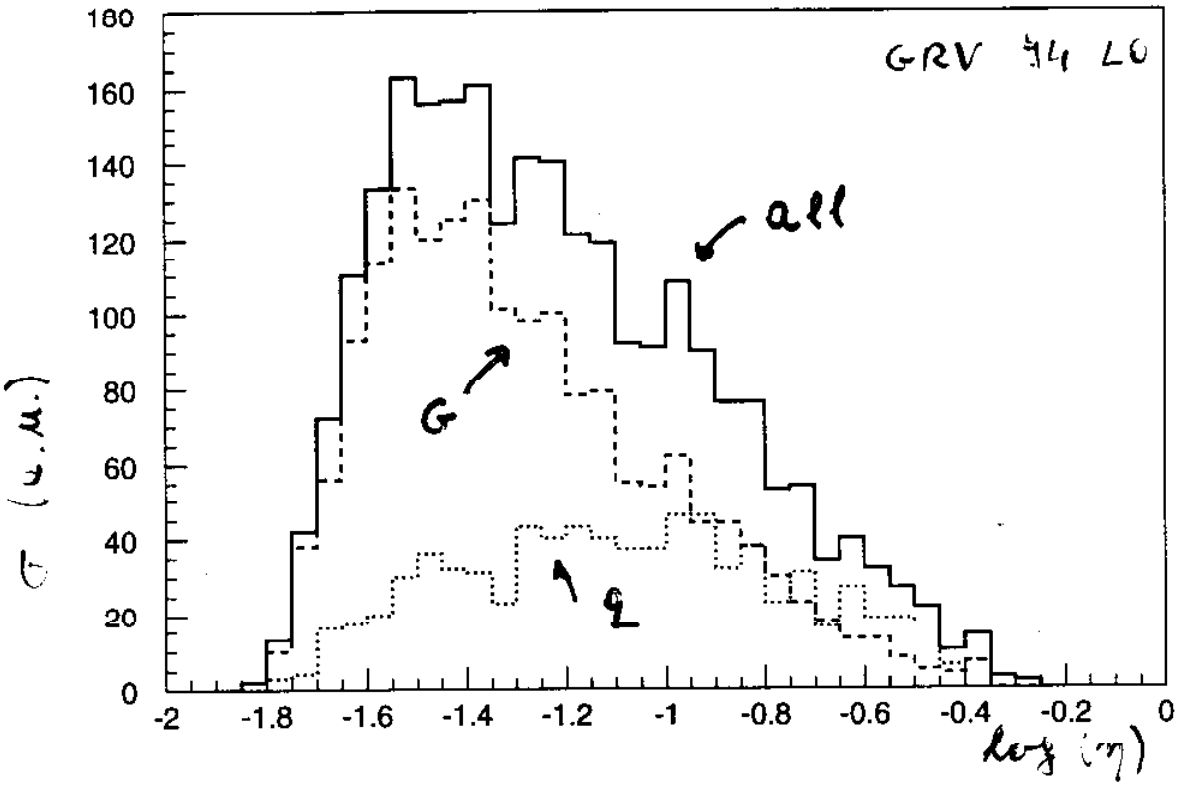
$p_T^{\pm} > 1$ GeV, $x_F^{\pm} > 0$, $m(+,-) > 2$ GeV

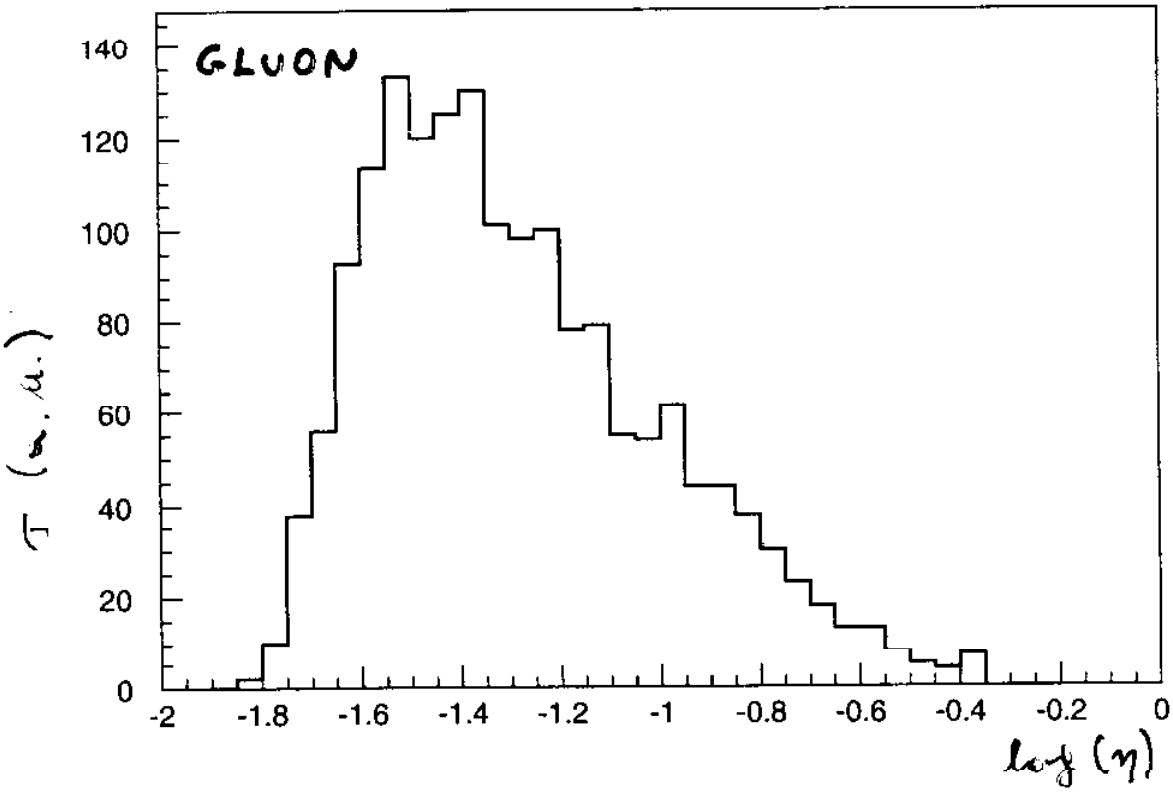




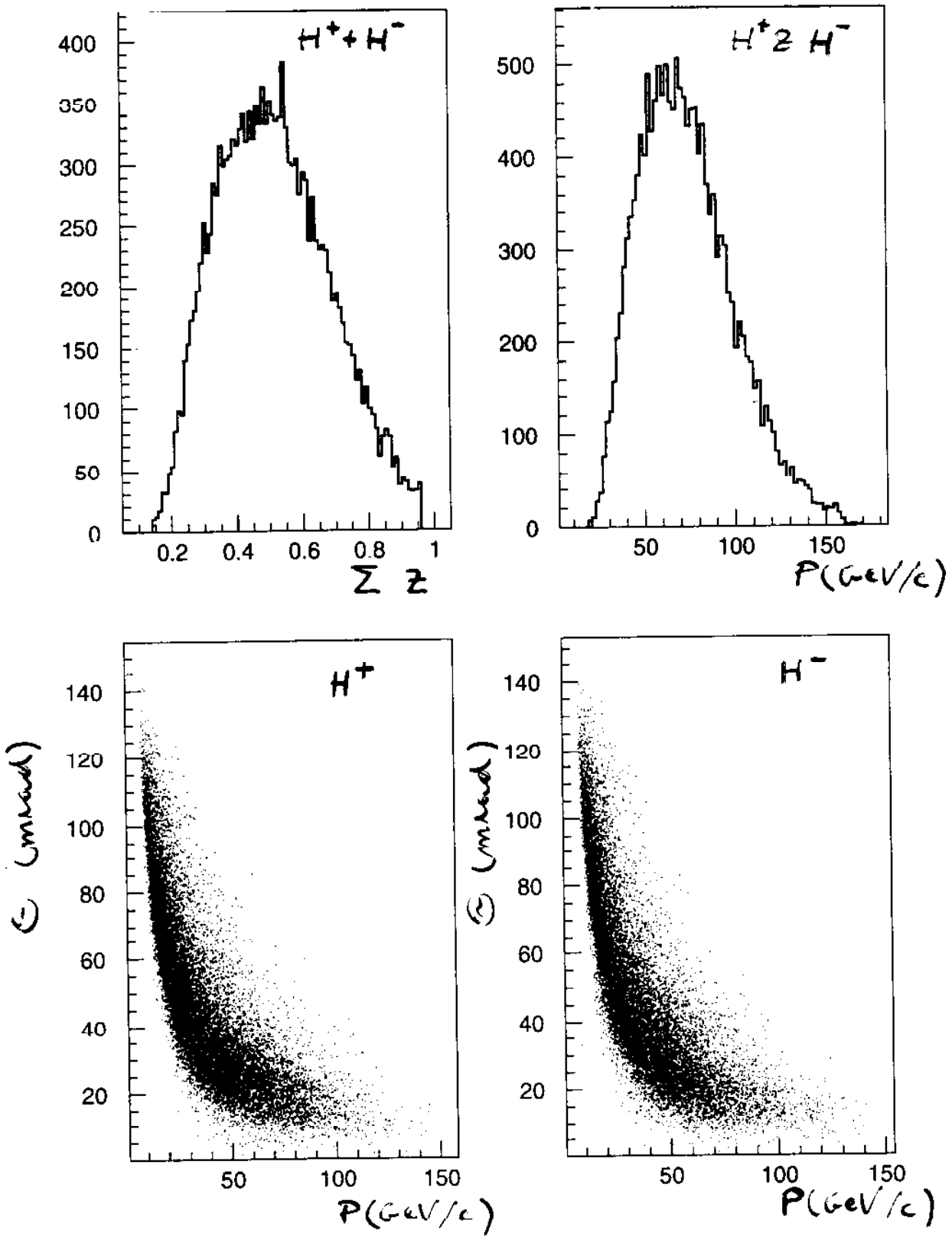
$K^+ K^-$ PAIR GLUON DISTRIBUTION

$p_T^{\pm} > 1$ GeV, $x_F^{\pm} > 0.1$, $m > 2$ GeV





LAB FRAME KINEMATICS (ACCEPTANCE OF H^+H^- PAIRS



THE ASYMMETRY $A_{LL}^{\gamma P \to H^+H^-}$

$$A_{LL}^{\gamma P \to H^+H^-}_{(K^+K^-)} \simeq \langle a_{LL}^{PGF} \rangle \langle \frac{\Delta G}{G} \rangle \frac{\sigma^{PGF}}{\sigma^{TOT}} +$$

$$+ \langle a_{LL}^{COM} \rangle \langle \frac{\Delta \mu}{\mu} \rangle \frac{\sigma^{COM}}{\sigma^{TOT}}$$

3 UNKNOWNS: $\frac{\Delta G}{G}$ $\frac{\Delta \mu}{\mu}$ $\frac{\sigma^{PGF}}{\sigma^{TOT}}$ $\left(\frac{\sigma^{PGF}}{\sigma^{COM}} \right)$

COMBINE $A_{LL}^{H^+H^-}$ and $A_{LL}^{K^+K^-}$

$$\begin{cases} A_{LL}^{K^+K^-} = A \cdot R + B \cdot (1-R) \\ A_{LL}^{H^+H^-} = A' \cdot R' + B' \cdot (1-R') \end{cases}$$

$A = \langle a_{LL}^{PGF} \rangle \langle \frac{\Delta G}{G} \rangle$

$B = \langle a_{LL}^{COM} \rangle \langle \frac{\Delta \mu}{\mu} \rangle$

$R = \sigma^{PGF} / \sigma^{TOT}$

$\rightarrow$ 6 UNKNOWNS & 2 EQUATIONS

BUT: $A \simeq A'$

$B \simeq B'$ REDUCE UNCERTAINTY

$R = \pi R'$

$\Rightarrow$ EXTRACT $\langle \frac{\Delta G}{G} \rangle$

$\langle \frac{\Delta \mu}{\mu} \rangle$ FROM S.I.

R FROM MC EV. GEN.

THE ASYMMETRY

PRELIMINARY RESULTS

ESTIMATES USING 200 GeV μ

$0.5 \leq y \leq 0.9$ $(W^2 > 200)$

$Q^2 \rightsquigarrow \emptyset$

AND GRV 94 LO (UNPOL.) + GS 96 (POL.) PDF'
SET A

CROSS SECTION FOR H^+H^- (K^+K^-)

$\sigma^{\mu P}_{TOT}$ $(Q^2 > 0.5) \simeq 50$ mb $\quad \sigma^{\mu P}_{KK} = \varepsilon \cdot \sigma^{\mu P}_{TOT}$

EXTRAPOLATE TO $Q^2 \rightsquigarrow \emptyset$ $\quad Q^2_{MIN} \sim 3 \times 10^{-3}$ GeV^2

$$\sigma^{\mu P} = \Gamma(Q^2, \nu, E) \frac{\sigma^{\gamma P}}{(1 + Q^2/M_0^2)^2}$$

SCALE HARD PROCESS
USE 10 GeV^2 LIKE FOR D.C. & J/ψ

$\sigma^{\mu P}_{TOT}$ $(Q^2 > Q^2_{MIN}) \simeq 150 - 200$ mb

$\sigma^{\mu P}_{KK} = \varepsilon \cdot \sigma^{\mu P}_{TOT}$ $\quad (Q^2 > Q^2_{MIN})$

ASSUME $\varepsilon(Q^2 > Q^2_{MIN}) = \varepsilon(Q^2 > 0.5)$

YIELDS $\quad \int \mathcal{L} = 2\ \mathrm{fb}^{-1}$ i.e. 1 year

$\sigma^{\gamma^* P} = 150$ mb $\rightarrow KK \begin{pmatrix} p_T^{\pm} > 1 \\ m > 2 \end{pmatrix}$ 60 K EVENTS

$\rightarrow HH \begin{pmatrix} p_T^{\pm} > 1.5 \\ m > 3 \end{pmatrix}$ 80 K EVENTS

THE ASYMMETRY

ROUGH ESTIMATE

$$A_{LL}^{\gamma P \to KK}\Big|_{\substack{\eta=0.1\\ Q^2=10}} \simeq -1 \cdot 0.36 \cdot \frac{2}{3} + 0.5 \cdot 0.24 \cdot \frac{1}{3}$$

$$\simeq -0.20$$

$$A_{LL}^{\gamma P \to HH}\Big|_{\substack{\eta=0.1\\ Q^2=10}} \simeq -1 \cdot 0.36 \cdot \frac{1}{2} + 0.5 \cdot 0.24 \, \frac{1}{2}$$

$$\simeq -0.12$$

SENSITIVITY

$P_B = 80\%$ $\quad P_T = 0.25/N$

$$\delta A_{LL} = \frac{1}{P_B D} \cdot \frac{1}{P_T} \cdot \frac{1}{\sqrt{N_{ev}}}$$

$A_{LL}^{\gamma P \to KK} \simeq -0.20 \pm 0.025$ $\quad \lesssim 0.05$

$\Longrightarrow \delta\langle \frac{\Delta G}{G} \rangle$

$A_{LL}^{\gamma P \to HH} \simeq -0.12 \pm 0.022$ $\quad \lesssim 0.08$

N.B. $\delta\left(\frac{\Delta G}{G}\right)$ DOMINATED BY SYSTEMATICS NOT BY STATISTICS