Factorization of Diffractive Di-Jet Production

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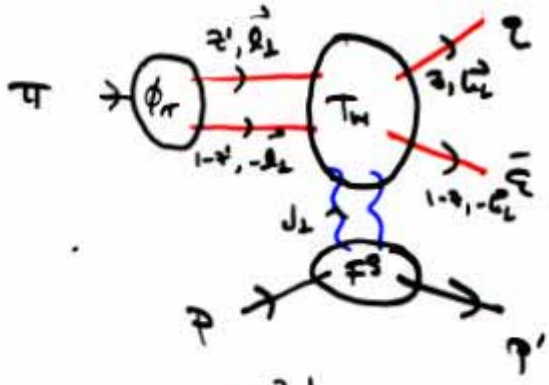
$$\mathcal{M}_{\pi \to \text{jet jet}} = \int_0^1 dz' \int_0^1 dx_1 \; \phi_\pi(z', \mu_F^2)\, T_H(z', x_1, \mu_F^2)\, F_i^g(x_1, \mu_F^2)$$

also $\bar{q}$ exchange

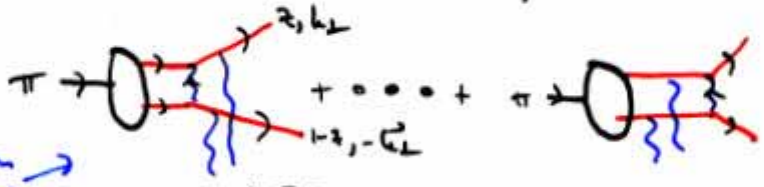


$k_\perp^2 \sim \frac{k_\perp^2}{z(1-z)}$

$\Delta_\perp^2 \ll k_\perp^2$

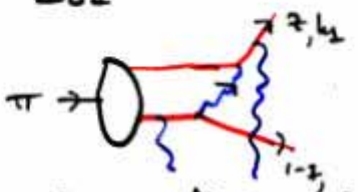
$k_\perp^2 \ll k_\perp^2$

3 diags in T_H



how gluon included in ϕ_π

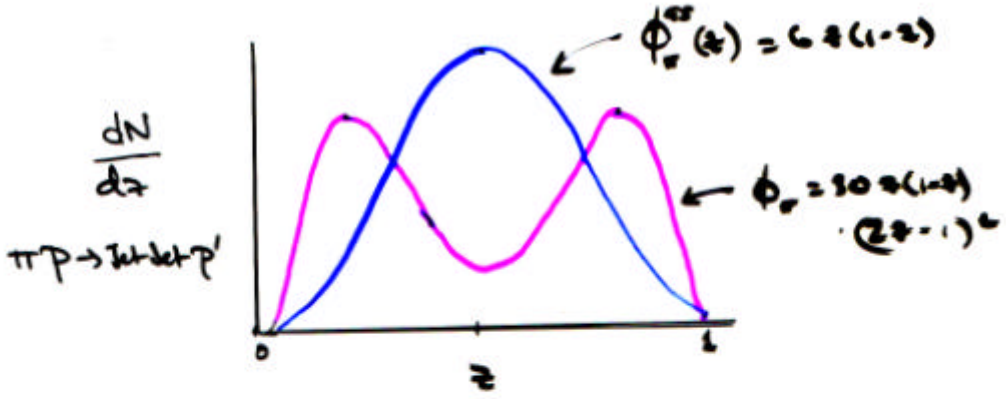
FSI FSI



dominant!

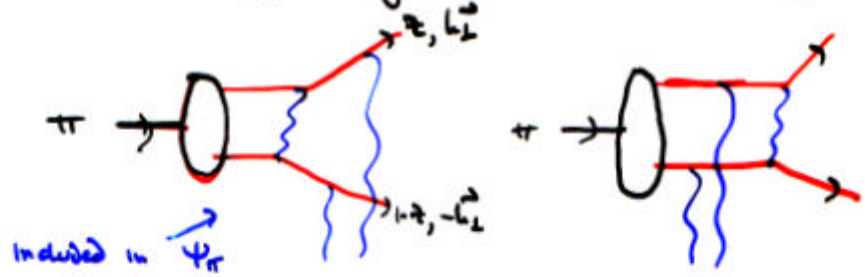
$\mathcal{M} \propto \phi_\pi(z)$

Real Emission, Absorp. — LL



From V. Braun, et al

* Additional Effect from Nuclear Filtering



$\sigma_{\pi A \to 2jet\,2jet\,A'} \sim \frac{A^2}{R_A^2} \sim A^{4/3}$ vs. $\sigma_{\pi A \to 2jet\,2jet\,A'} \sim A^{1}$

$\therefore \quad \mathcal{M} \propto \phi_\pi(z, k_T^2)$ in nucleus

Bertsch Gribov Guzey SLB

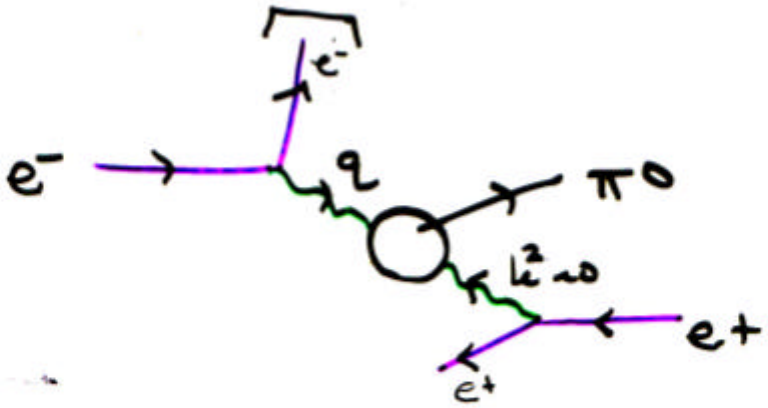
Need $k_\perp$ integral

Photon-to-Pion

Transition Form Factor

$F_{\gamma\pi}(q^2)$

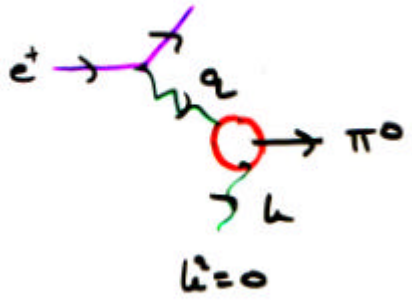
* Measure in e^+e^- colliders



CLEO

$\gamma^*\gamma \to \pi^0, \eta, \eta', \eta_c \ldots$

Simplest example of exclusive process

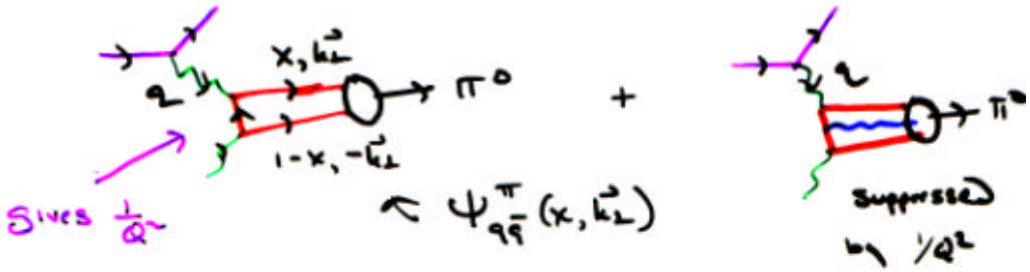


$F_{\gamma\pi^0}(q^2)$

$\pi^0 \to \gamma\gamma$ at $q^2=0$.

For $Q^2 \gg \Lambda^2_{QCD}$ analyse in PQCD

Large Q^2

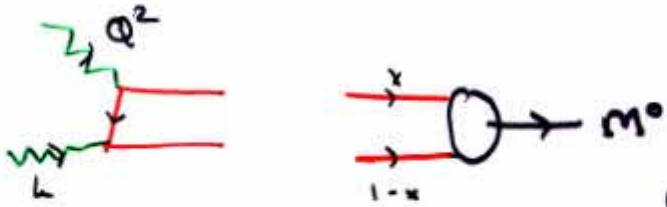


$\sim \Psi^{\pi}_{q\bar{q}}(x, \vec{k}_\perp)$

* $F_{\gamma\pi^0}(Q^2) = \frac{1}{Q^2} 2\sqrt{n_c}\,(e_u^2 - e_d^2) \int_0^1 dx \left(\frac{1}{x} + \frac{1}{1-x}\right) \phi_\pi(x, Q^2)$

* $\phi_\pi(x,Q) = \int^{Q} \frac{d^2k_\perp}{16\pi^3}\, \Psi_{q\bar{q}}(x, \vec{k}_\perp)$ pion distribution amplitude

PQCD : $F_{\gamma \to M^0}(Q^2) \sim \frac{1}{Q^2} \int_0^1 \frac{dx}{1-x} \phi_M(x, \bar{Q})$



T_H $\qquad \phi_M(x,Q) = \int^{k_\perp^2 < \bar{Q}^2} d^2k_\perp \, \Psi_{q\bar{q}}(x, \vec{k}_\perp)$

* $T_H(\gamma^*\gamma \to q\bar{q}) \sim \frac{1}{Q^2(1-x)}$ $\qquad \alpha(Q)^n$ $\qquad$ collinear

* Higher Fock states : $\frac{1}{Q^4}$ 

Other diagrams $\mathcal{O}(\alpha_s(Q^2))$!

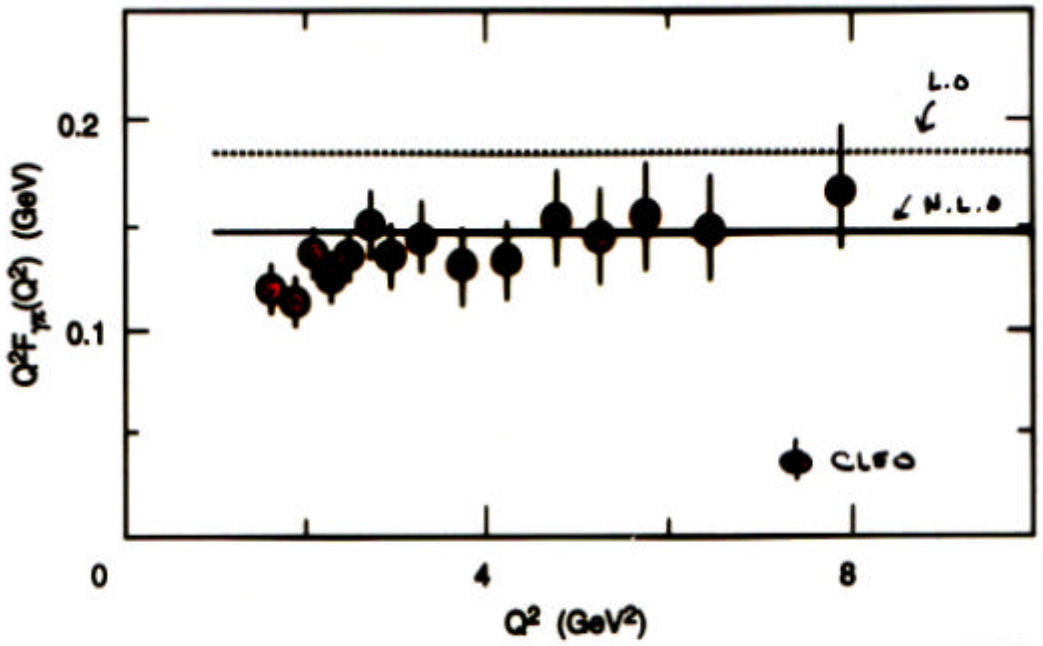
* $\phi_M(x,Q) = \sum_{n=0}^{\infty} a_n P_n(x) \left(\ln \frac{Q^2}{\Lambda^2}\right)^{-\gamma_n}$ 

log evolution

* $\lambda_M = \lambda_q + \lambda_{\bar{q}} = 0$. HHC test in $\int_0^1$

** Small part of Fock state dominates

$\phi_M \sim \Psi(x, b_\perp \sim \frac{1}{Q})$

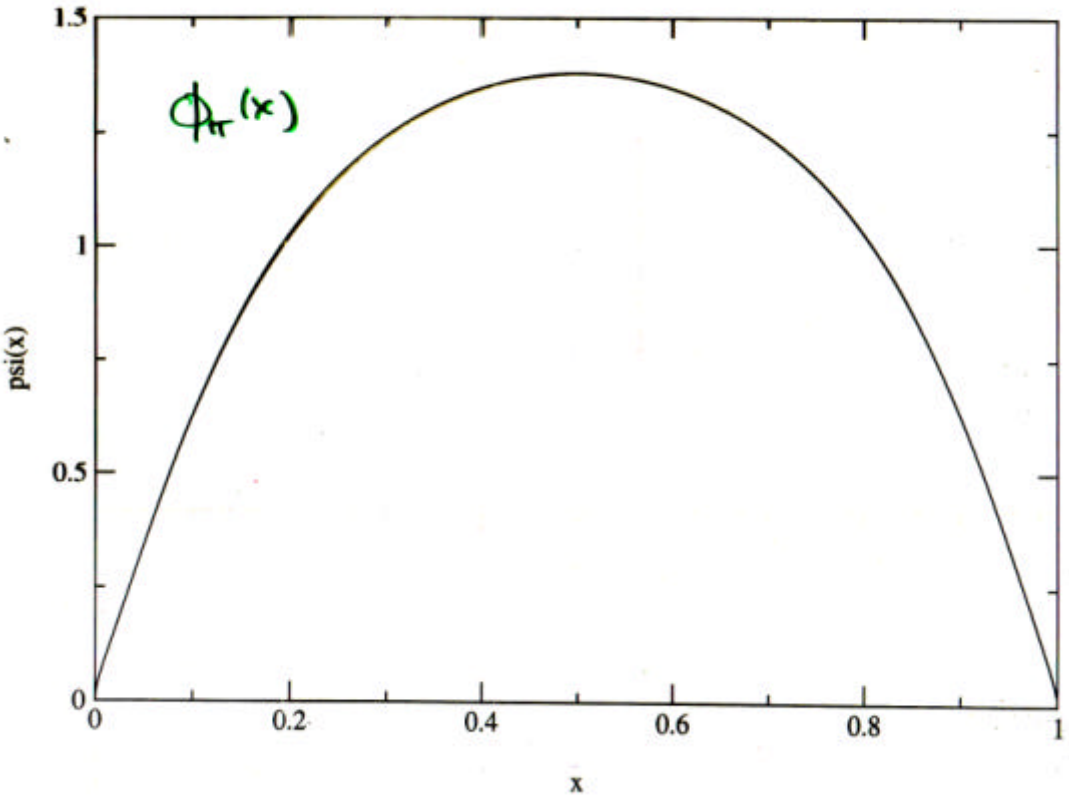


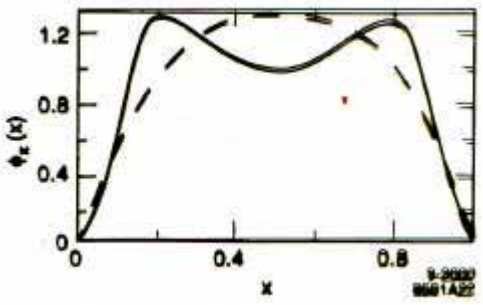
assumes $\phi_\pi(x) = \phi_{asymptotic}(x)$

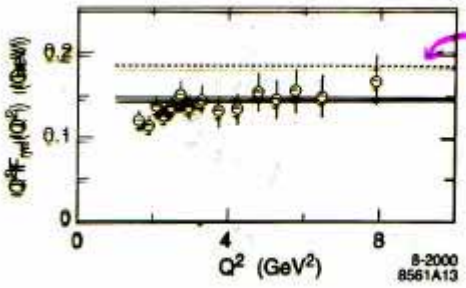
$= \sqrt{3} f_\pi \times (1-x)$

Transverse Lattice + DLCQ

Burkardt + Seal





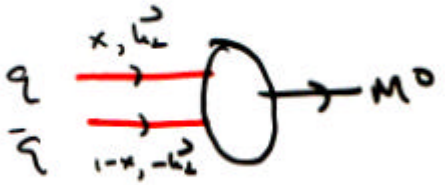


asymp
NLO

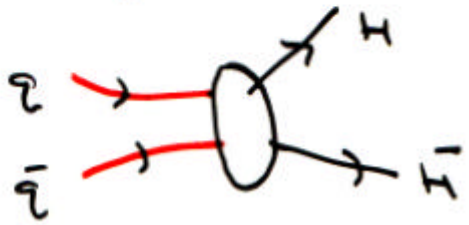
— transverse Lattice/DLCQ
Dalley

--- Asymptotic dist. ampl.
Burkardt

Hadronization at Amplitude Level



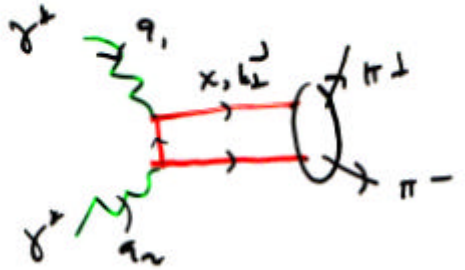
$\psi_{q\bar{q}\to M^0}(x, \vec{k}_\perp)$



$\psi_{q\bar{q}\to H\bar{H}}$

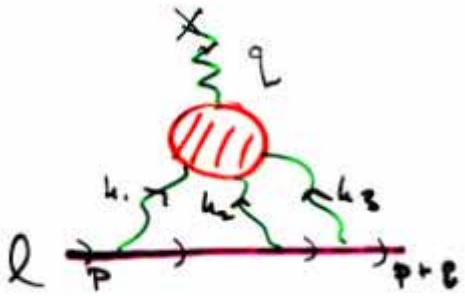
* coalescence q, $q\bar{q} \Rightarrow$ hadrons

- Measure in $\gamma^*(q_1)\,\gamma^*(q_2) \Rightarrow$ hadrons

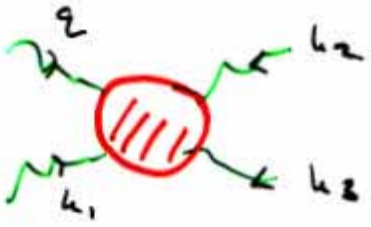


$$\phi_{q\bar{q}\to\pi^+\pi^-}(x, Q) = \int^{Q} d^2k_\perp \, \psi_{q\bar{q}\to\pi^+\pi^-}(x, \vec{k}_\perp)$$

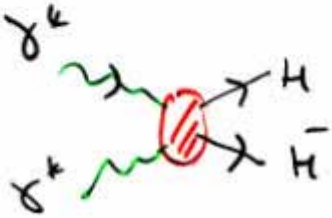
- Generalized Distribution Amplitudes Diehl et al



$(g-2)_\ell$: coeff of q^2



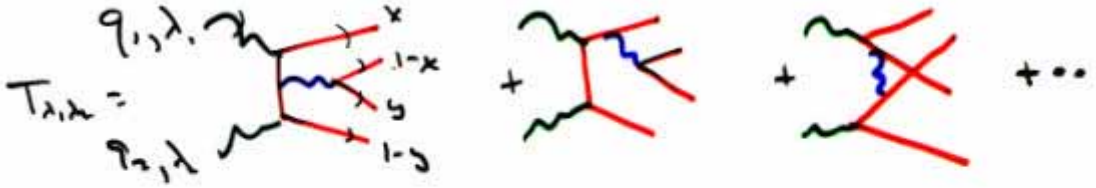
Important input from



, etc

Build effective theory

$\gamma\gamma \to H\bar{H}$

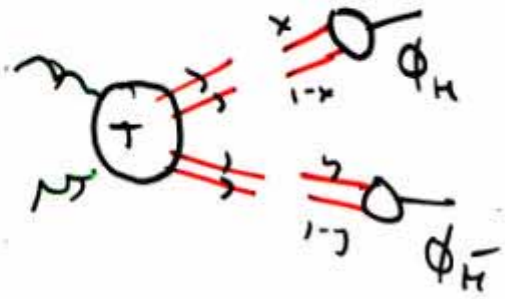


$$\mathcal{M}_{\lambda_1\lambda_2}(s,\theta_{cm}) = \int_0^1 dx \int_0^1 dy$$

$$\phi^*_H(x,Q)\,\phi^*_{\bar{H}}(y,Q)\,T_{\lambda_1\lambda_2}(x,y;s,Q)$$

Factorization theorem

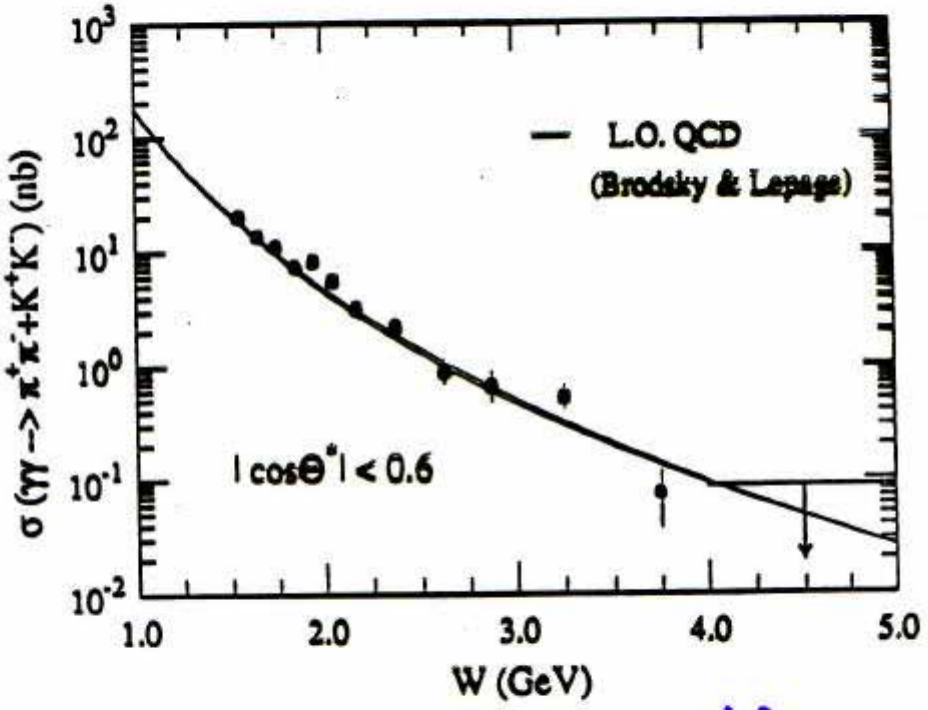
* Separates perturbative $T_{\lambda_1\lambda_2}$ from non-perturbative $\phi_H(x,Q)$



* ϕ_H universal ; no FSI !

$\gamma\gamma \to \pi^+\pi^-, K^+K^-$

CLEO

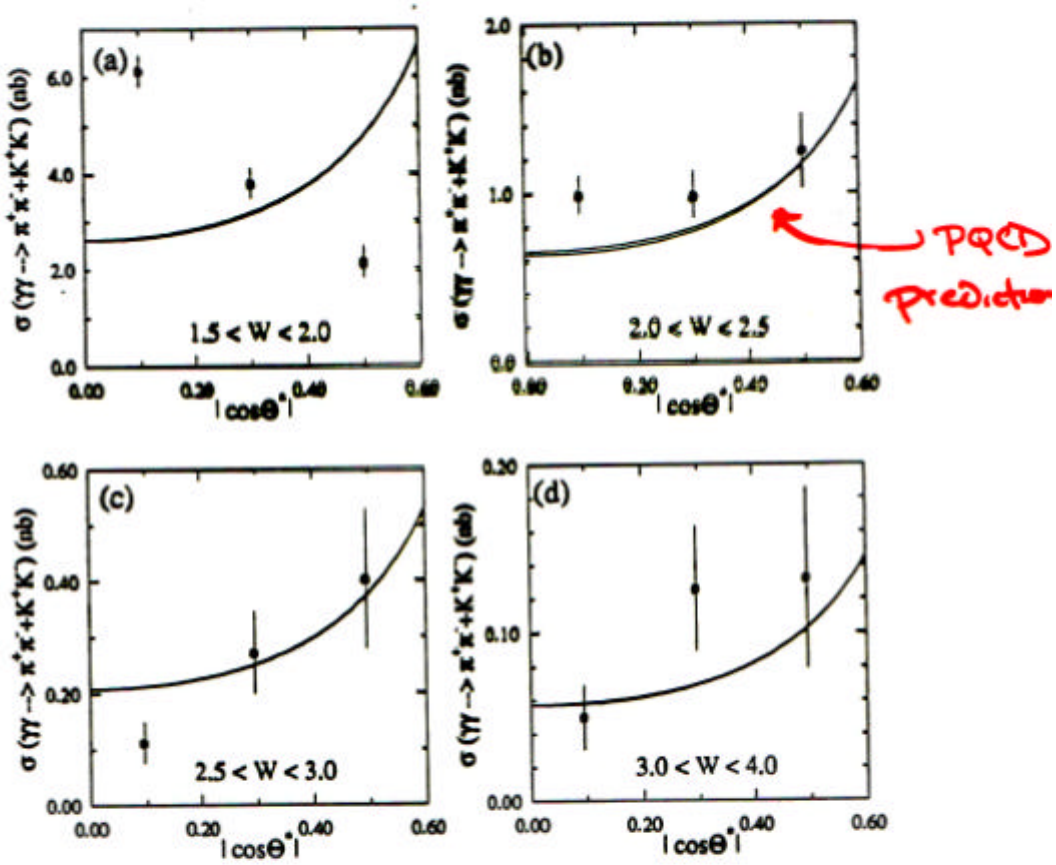


$W_{\gamma\gamma}$

Normalization from $F_{\pi\pi}(s)$, $F_K(s)$

$\gamma\gamma \to \pi^+\pi^-, K^+K^-$ (θ^* dep)

CLEO



$|\cos\theta^*|$

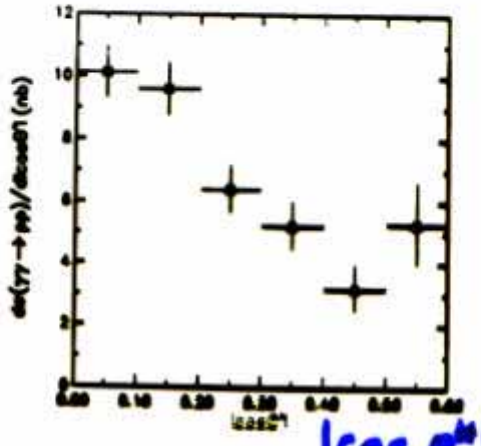
Evidence for PQCD at $W_{\gamma\gamma} \gtrsim 2.5$ GeV

HPP

θ^* : (in $\gamma\gamma$ CM)

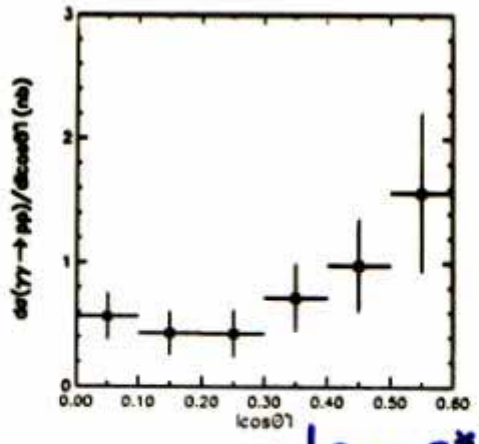
$\gamma\gamma \to p\bar{p}$

CLEO



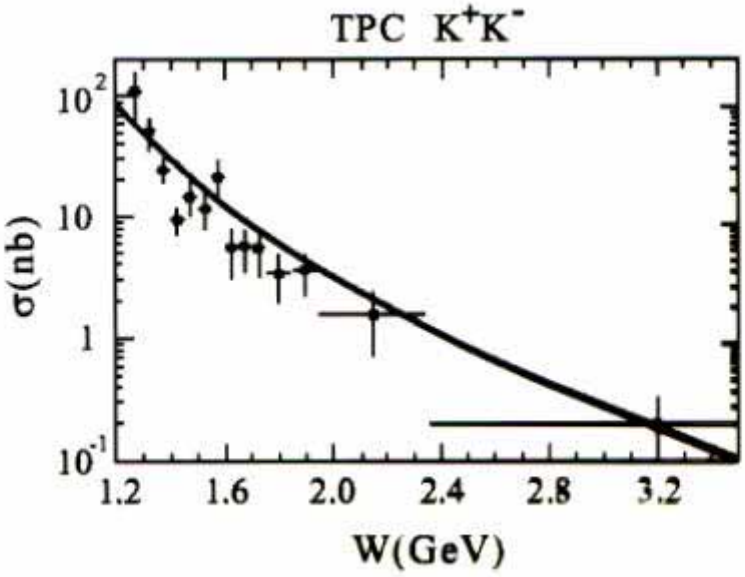
$2 \leq W \leq 2.5$ GeV

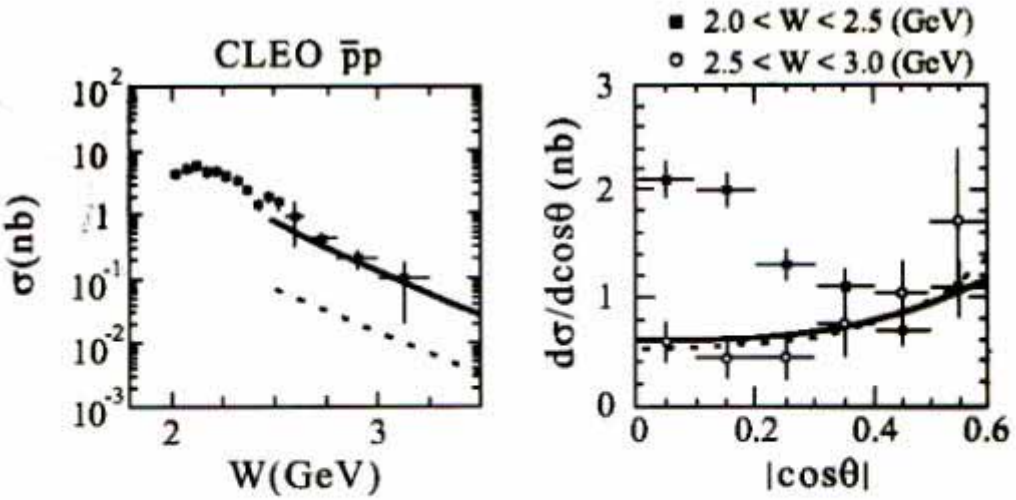
CLEO



$W > 2.5$ GeV

Remarkable transition to PQCD for! HPP


TPC K^+K^-
10^2
10
1
10^{-1}
σ(nb)
1.2
1.6
2.0
2.4
2.8
3.2
W(GeV)


CLEO $\bar{p}p$
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
σ(nb)
2
3
W(GeV)
■ 2.0 < W < 2.5 (GeV)
○ 2.5 < W < 3.0 (GeV)
3
2
1
0
dσ/dcosθ (nb)
0
0.2
0.4
0.6
|cosθ|

↑
two regimes

BIL

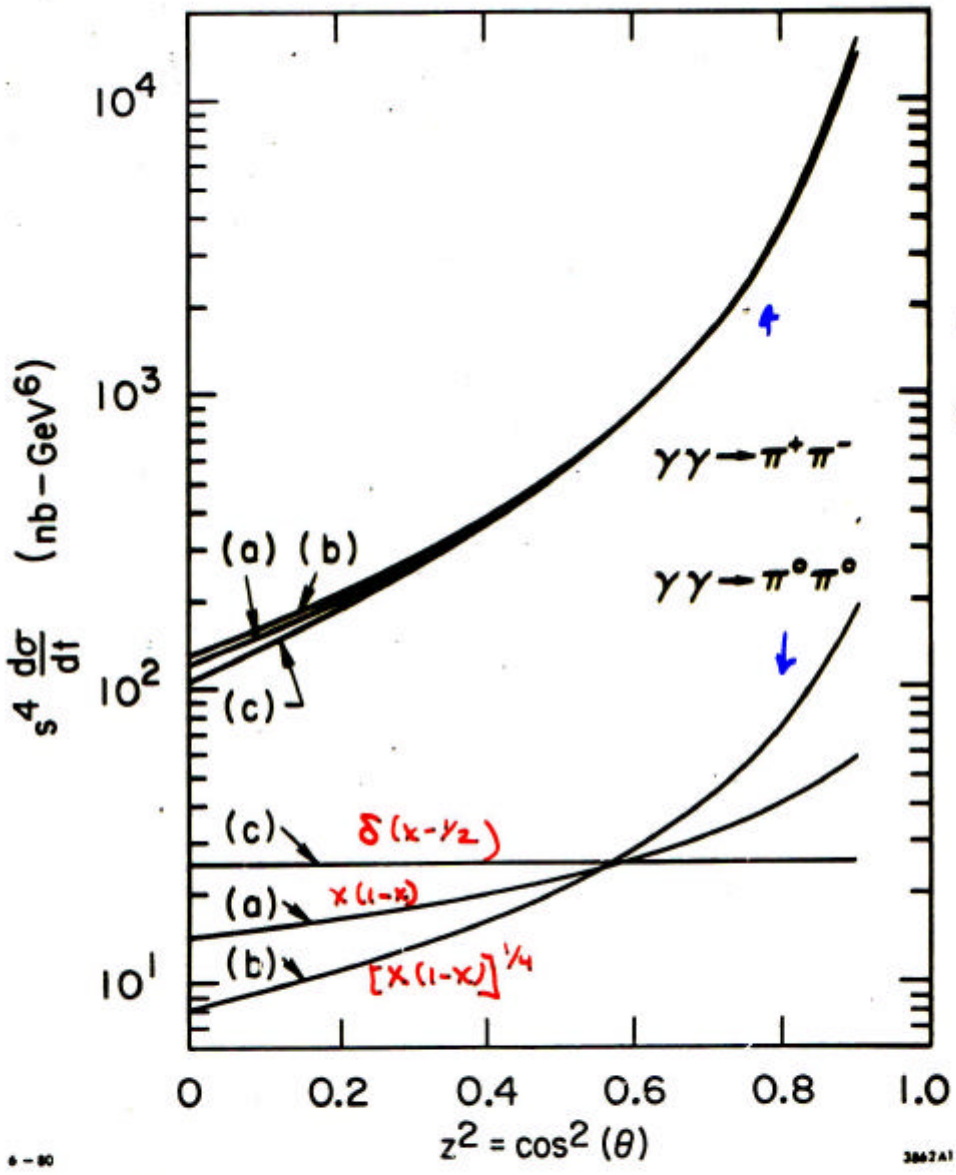
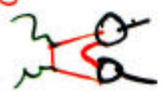
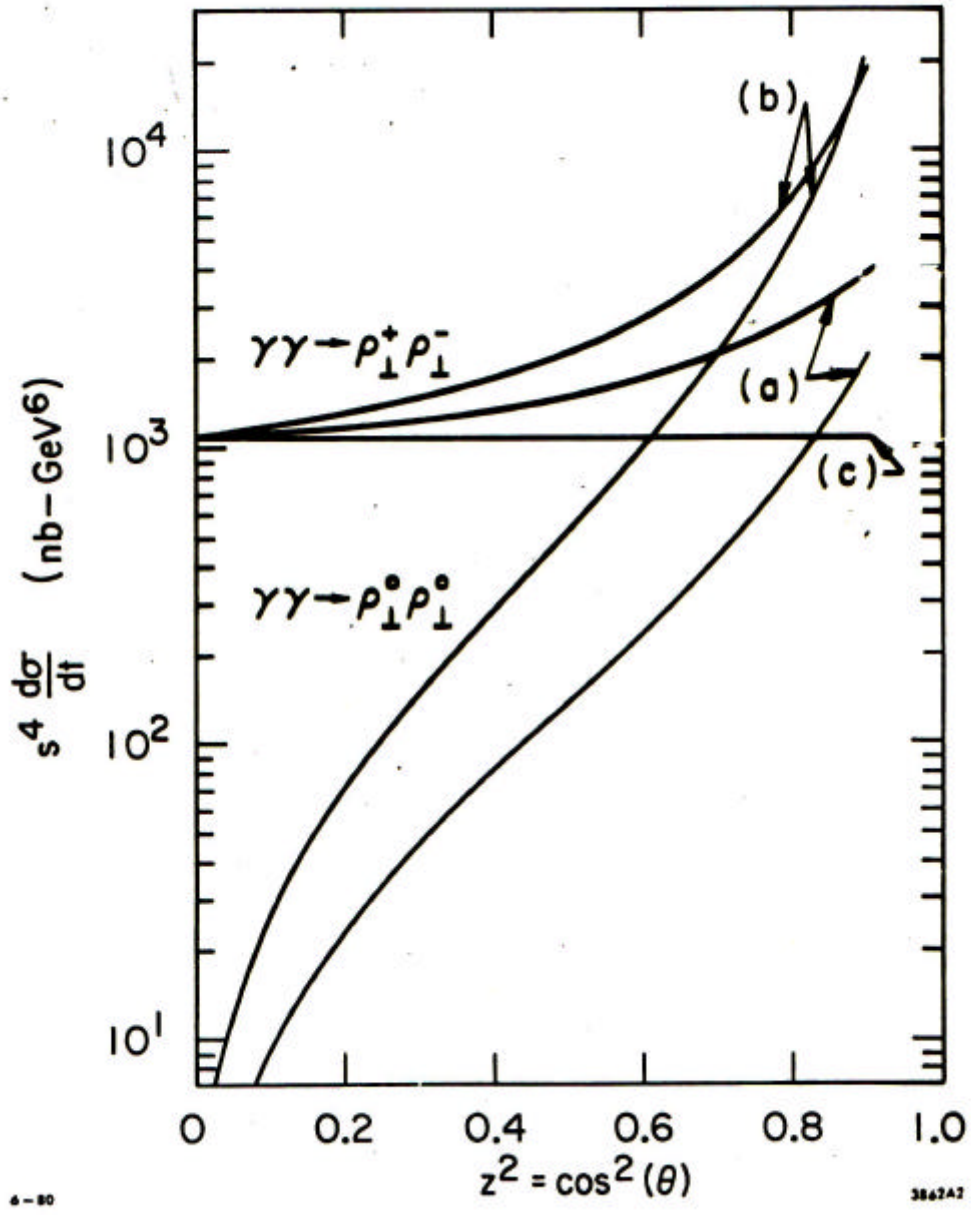


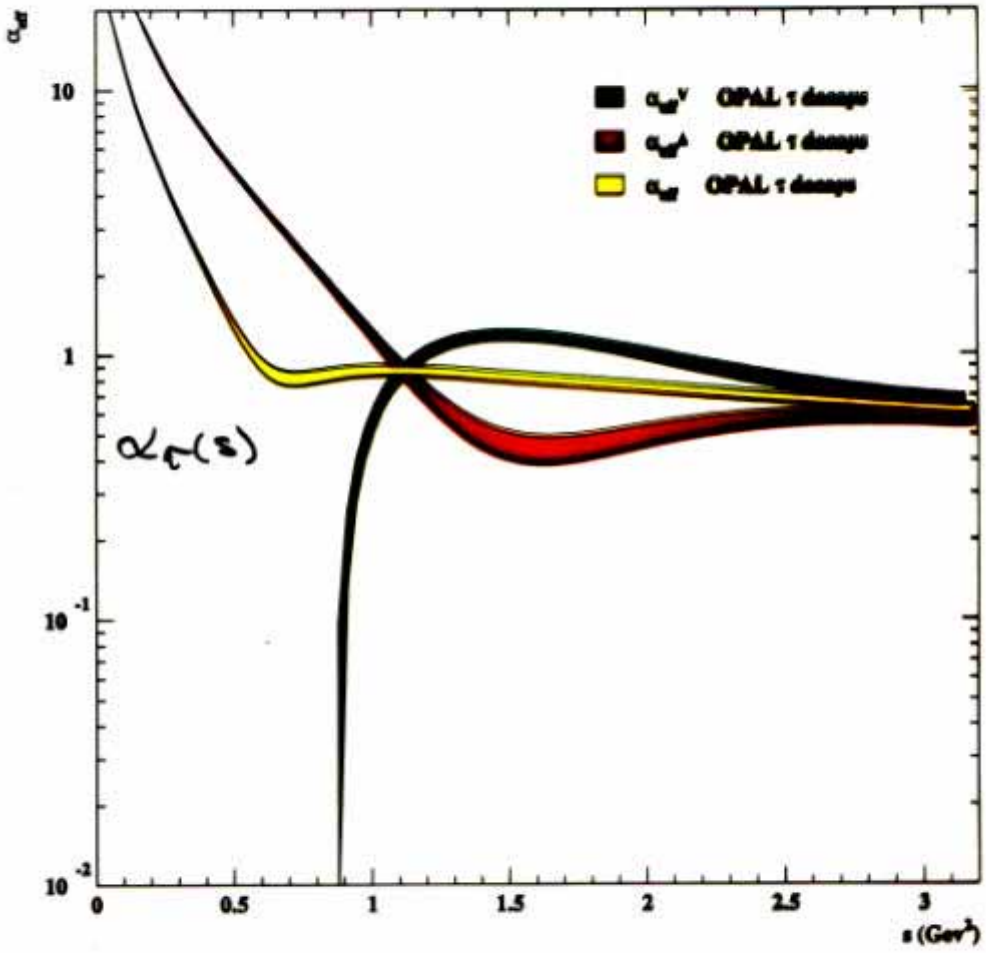
Fig. 3

strong suppression of $\gamma\gamma \to \pi^0\pi^0$

not true if  only


(b)
(a)
(c)
$\gamma\gamma \to \rho_\perp^+ \rho_\perp^-$
$\gamma\gamma \to \rho_\perp^0 \rho_\perp^0$
10^4
10^3
10^2
10^1
$s^4 \frac{d\sigma}{dt}$ (nb−GeV6)
0
0.2
0.4
0.6
0.8
1.0
$z^2 = \cos^2(\theta)$
6-80
3862A2

S. Menke
(predict)
SJB, Menke



$\alpha_\tau \sim$ flat
~ 1
not .3 to .4

Conclusions

QCD Phenomena and Light-Cone Wavefunctions

* Universal, frame-independent $\{\psi_n(x, k_\perp, \lambda)\}$

* Distribution amplitudes $\begin{cases} \phi_M(x, Q) \\ \phi_B(x_1, x_2, Q) \end{cases}$

  - key hadronic input to factorizable exclusive amplitudes

  - Unify B-physics, Form Factors, high momentum transfer amplitudes

* New experimental tool: diffractive jet prod

* Novel Phenomena

  - Color Transparency
  - Intrinsic Charm
  - Hidden Color
  - Extremum physics: $x \to 1$
    high $k_\perp$
    heavy quark threshold

* New theory methods
  DLCQ, Transverse Lattice