RHIC Winter Mtg
L.B.L.

S. Brodsky
SLAC 1-7-99

Novel Peripheral Processes at RHIC

Exclusive Reactions

* Collisions where nuclei remain intact

* Strong coherence Amplitude $\sim Z_1 Z_2$ or $A_1^{2/3} A_2^{2/3}$

* nuclei suffer small momentum transfer $e^{-R_A^2 q_\perp^2}$ suppression

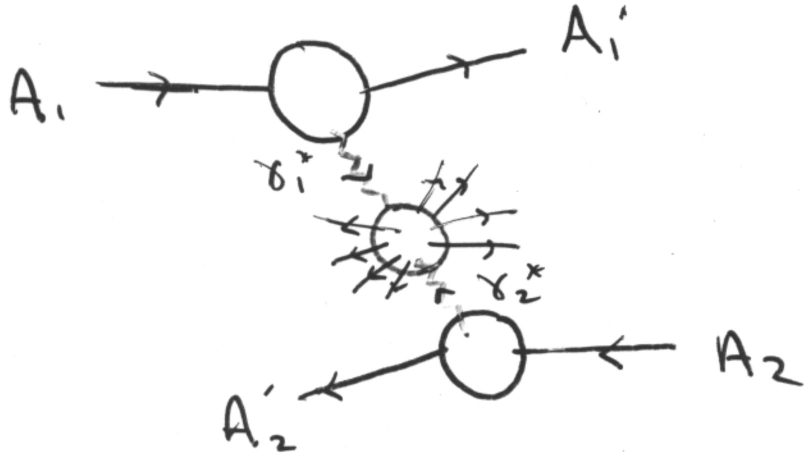
* Many processes pioneered by S. Klein et al + calculated

* See also Cahn + Jackson

  SJB, Kinoshita, Terazawa

* Physics of Double Pomeron, Rapidity Gaps: $\gamma\gamma$, Pomeron, Odderon induced.

Peripheral Collisions at RHIC



$A_1 A_2 \to A_1' A_2' X$

nuclei remain intact

study: $\gamma_1^*(q_1^2)\,\gamma_2^*(q_2^2) \to$

large impact separation

Power of Coherence

$$\sigma^{\gamma\gamma}_{A_1 A_2} = Z_1^2 Z_2^2 \, \sigma^{\gamma\gamma}_{e^+e^-} \, F_1^2(q_1^2)\, F_2^2(q_2^2)$$

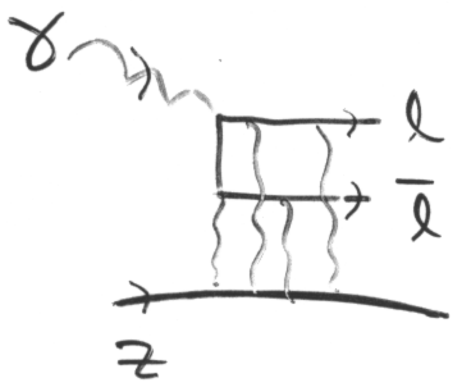
$$\times \log^2 s/m_N^2$$

coherent for $-q^2 R_A^2 < 1$

$\therefore$ Nearly-real photon photon collisions

S. Klein, refs therein

Coherent Lepton-Pair Production – All Orders Analysis



Bethe Heitler

$$\sigma_{LO} = \frac{\alpha (Z\alpha)^2}{m_\ell^2} \int \frac{db_\perp^2}{b_\perp^2}$$

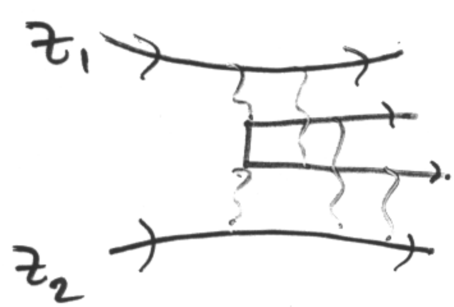
$$= \frac{\alpha (Z\alpha)^2}{m_\ell^2} \left[\log s/m_\ell^2 + k \right]$$

Bethe Maximon Davies

$$\sigma_{HO} = \frac{\alpha (Z\alpha)^4}{m_\ell^2} F((Z\alpha)^2)$$

no log!

known to all orders!

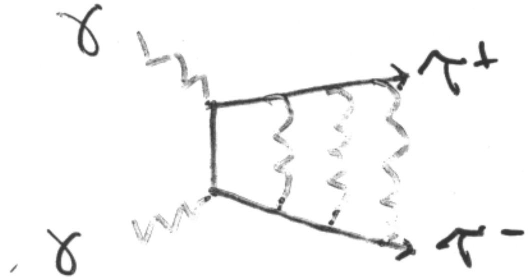


$$\sigma_{LO} = (Z_1\alpha)^2 (Z_2\alpha)^2 \int \frac{db_1^2}{b_1^2} \int \frac{db_2^2}{b_2^2}$$

double log <u>only</u> from LO

Schwinge
Sommerfe
Fermi

Coulomb Effects at Threshold



$$\sigma = \sigma_0 \left[\frac{X}{1-e^{-X}} \right]$$

$$X = \pi \frac{\alpha(4m^2\beta^2)}{\beta}$$

$\beta = v_\tau$

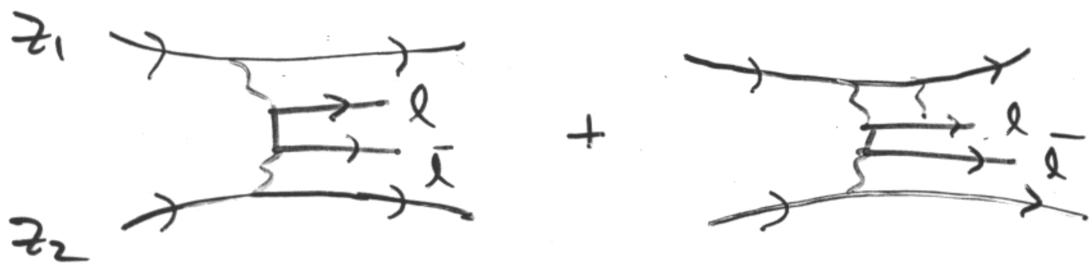
α evaluated at soft scale!

not $\mu = m_\tau$

Crucial for $b\bar{b}$, $t\bar{t}$ productio

QCD: $\alpha \Rightarrow C_F \alpha_V(4m^2\beta^2)$

Lepton-Pair Asymmetry



interference

lepton / anti-lepton asymmetry $\left\{ \begin{array}{l} \text{energy} \\ \text{angle} \end{array} \right.$

negative lepton attracted to positive nucleus

$\underline{\gamma Z \to \mu^+ \mu^- Z}$ measured at DESY in 60's

Ting et al.

$$\text{Asymmetry} = \frac{\sigma(E_\ell > E_{\bar{\ell}}) - \sigma(E_\ell < E_{\bar{\ell}})}{+}$$

$$= (Z\alpha)\, F(E_i, \theta_{cm})$$

SJB + Gillespie

ref: BKT
Budnev et al

$\gamma\gamma$ Collisions

polarization from scattering plane

Channels:

$\gamma\gamma \to$ Hadrons

$\gamma\gamma \to$ exclusive channels

$\gamma\gamma \to$ resonances

$\gamma\gamma \to H\,X$ — single particle inclusive

$\gamma\gamma \to$ jets

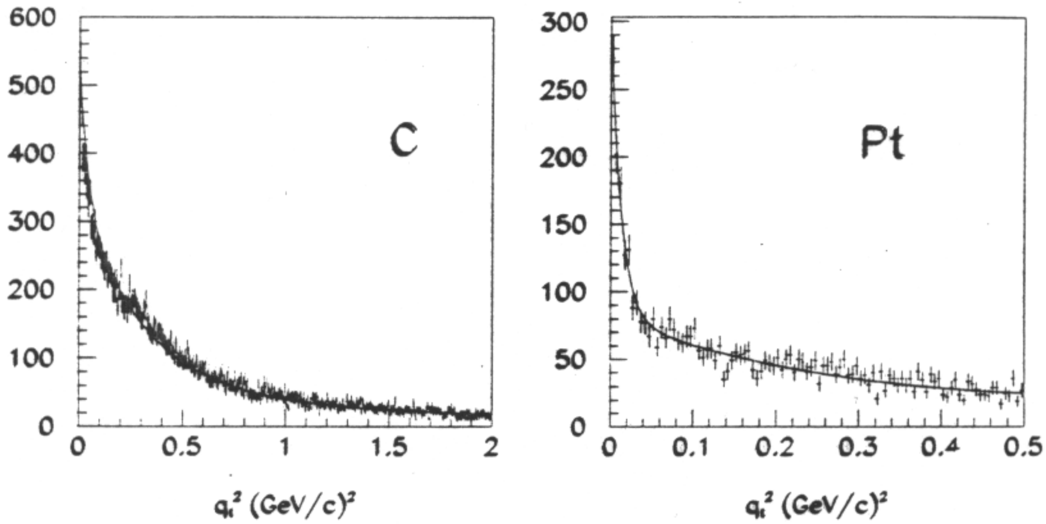
RHIC: primarily low

$$\hat{s} = (q_1 + q_2)^2$$

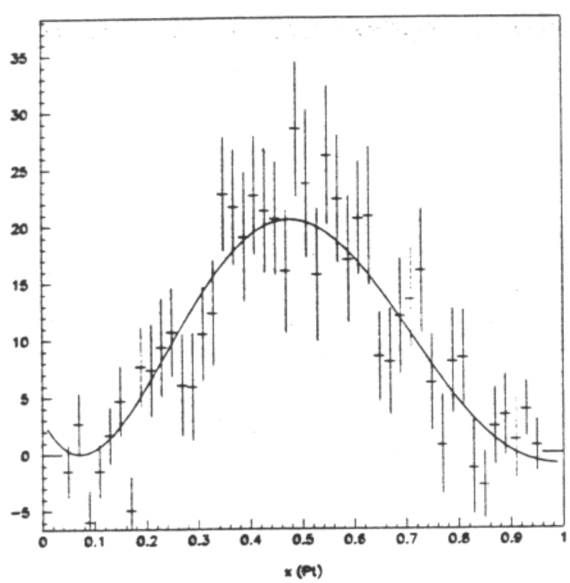
Monitor: $\gamma\gamma \to l\bar{l}$

$$R^{\gamma\gamma}_{\pi\pi} = \frac{\sigma(\gamma\gamma \to \pi^+\pi^-)}{\sigma(\gamma\gamma \to \mu^+\mu^-)}$$

flux factors cancel
same $\hat{s}, \hat{t}$



q_t^2 distributions of di-jets for C and Pt targets. The lines are fits of the MC simulations to the data.



The preliminary x distribution of the diffractive di-jets for platinum target. The line is a fit to a wave function with 90% asymptotic and 10% CZ.

$\gamma\gamma \Rightarrow$ Exclusive Channels

$\gamma\gamma \to \pi^+\pi^-, K^+K^-, \ldots$ meson pairs

$\to \rho^+\rho^-, \ldots$ helicity dependence

$\to p\bar{p}, \Delta\bar{\Delta}, \ldots$ baryon pairs

$\to \pi^0, \eta, \eta', \text{gluonia}\,(C=+)$ resonances

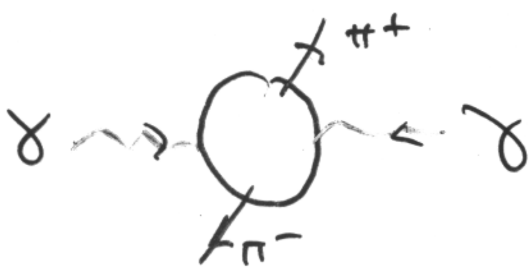
$\to D^+D^-$ charm

$\ldots$

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

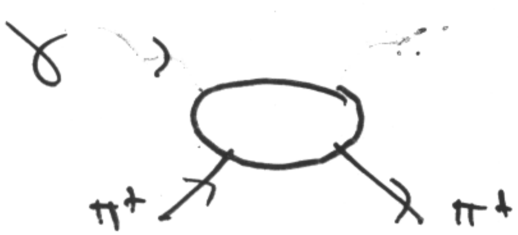
one of the simplest QCD processes

Mandelstam



$$\frac{d\sigma}{dt}(s,t) \quad \gamma\gamma \to \pi^+\pi^-$$

$$s \Leftrightarrow t$$

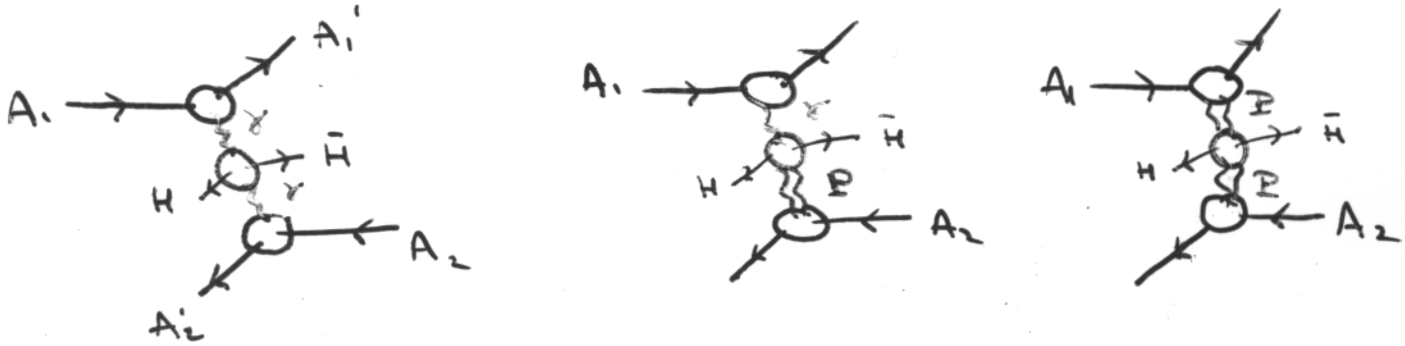


$$\frac{d\sigma}{dt}(s,t) \quad \gamma\pi^+ \to \gamma\pi^+$$

cross to Compton

Interesting complication in

coherent nuclear collisions



$\mathbb{P}$: "pomeron", gluon exchange,
vector meson exchange
Reggeon
QCD Van der Waals

$\mathbb{P}$: * interference with photon exchange possible

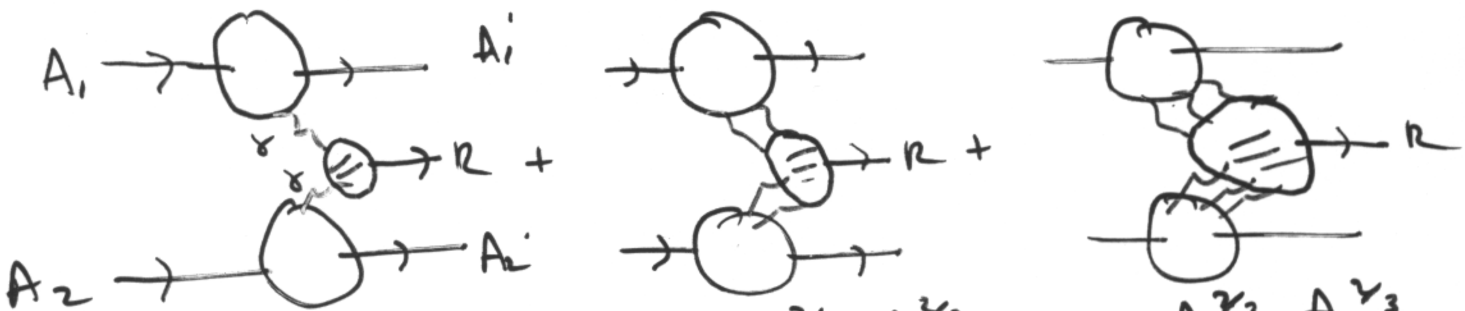
* difference dependence on $q_\perp^2$

* power-law suppression at high p_T (dimensional counting)

Coherent Production of Resonances at RHIC

F. Low
BKT
Bodner et al.

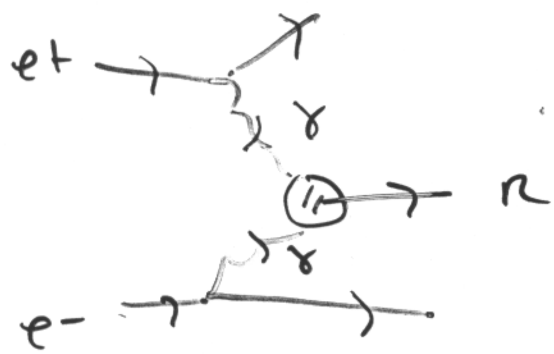
see also Nystrand + Klein



$Z_1 Z_2$ $A_1^{2/3}\ A_2^{2/3}$ $A_1^{2/3}\ A_2^{2/3}$

Compare with

Note: # $f_2(1270) = 2\times 10$
at RHIC



Compare with CLEC
search for

$f_J(2220) \to \pi^+\pi^-$

high "stickiness" Ch

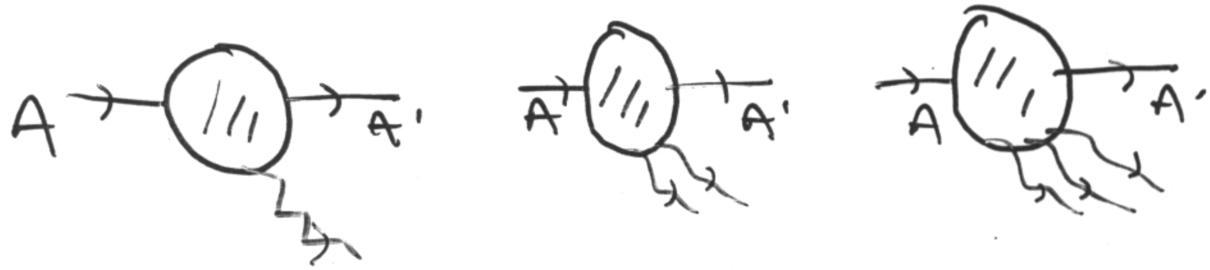
$P_T(R) < 30$ MeV, central rapidity

Use Z, A-dep to discriminate

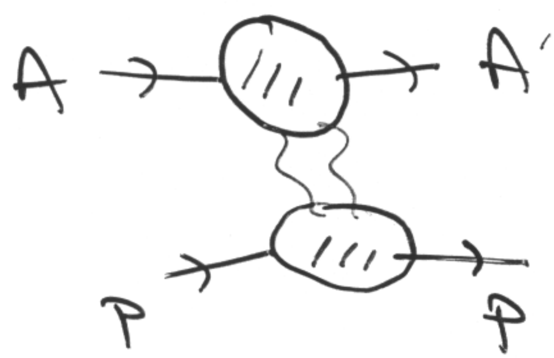
$b_\perp$ dep.

Use A and Z dependence

to discriminate coherent mechanisms

* 

	γ	Pomeron	Odderon
nuclear scaling of coupling	Z	$i\,A^{2/3}$	$i\,A^{2/3}$



Pomeron shadowing

$$\mathrm{Im}\,\mathcal{M}(0^\circ) \propto s\,\sigma_{TOT} \propto A^{2/3}$$

(surface)

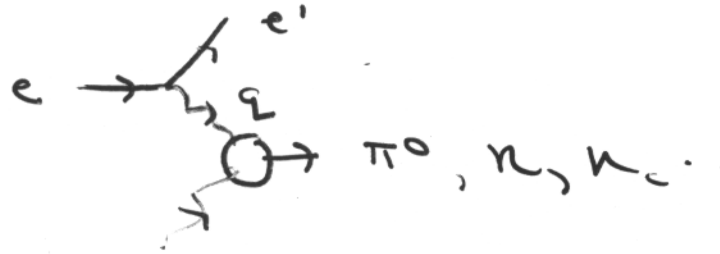
* No interference: γ with Pomeron

* Measure "forward" elastic amplitude

$$\frac{d\sigma}{dt}_{A_1A_2\to A_1A_2} \sim \pi\left(A_1^{1/3} + A_2^{1/3}\right) e^{+R_1^2+R_2^2}$$

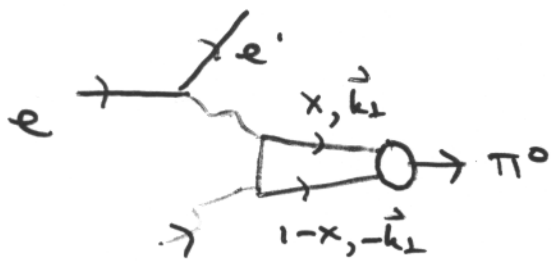
Simplest example of exclusive process

$q^2 = -Q^2$

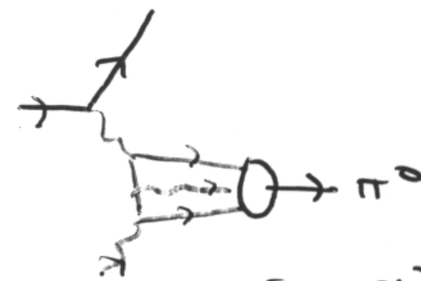


$$\frac{d\sigma}{dQ^2} \sim \frac{1}{Q^6}$$

$Q^2 \gg \Lambda^2_{QCD}$ $\qquad F_{\gamma\pi^0}(Q^2)$



$+$



suppressed by $\frac{1}{Q}$

$$F_{\gamma\pi^0}(Q^2) = \frac{1}{Q^2}\, 2\sqrt{N_c}\,(e_u^2 - e_d^2) \int_0^1 \frac{dx}{x(1-x)}\, \phi_\pi(x, \tilde{Q})$$

Pion distribution amplitude

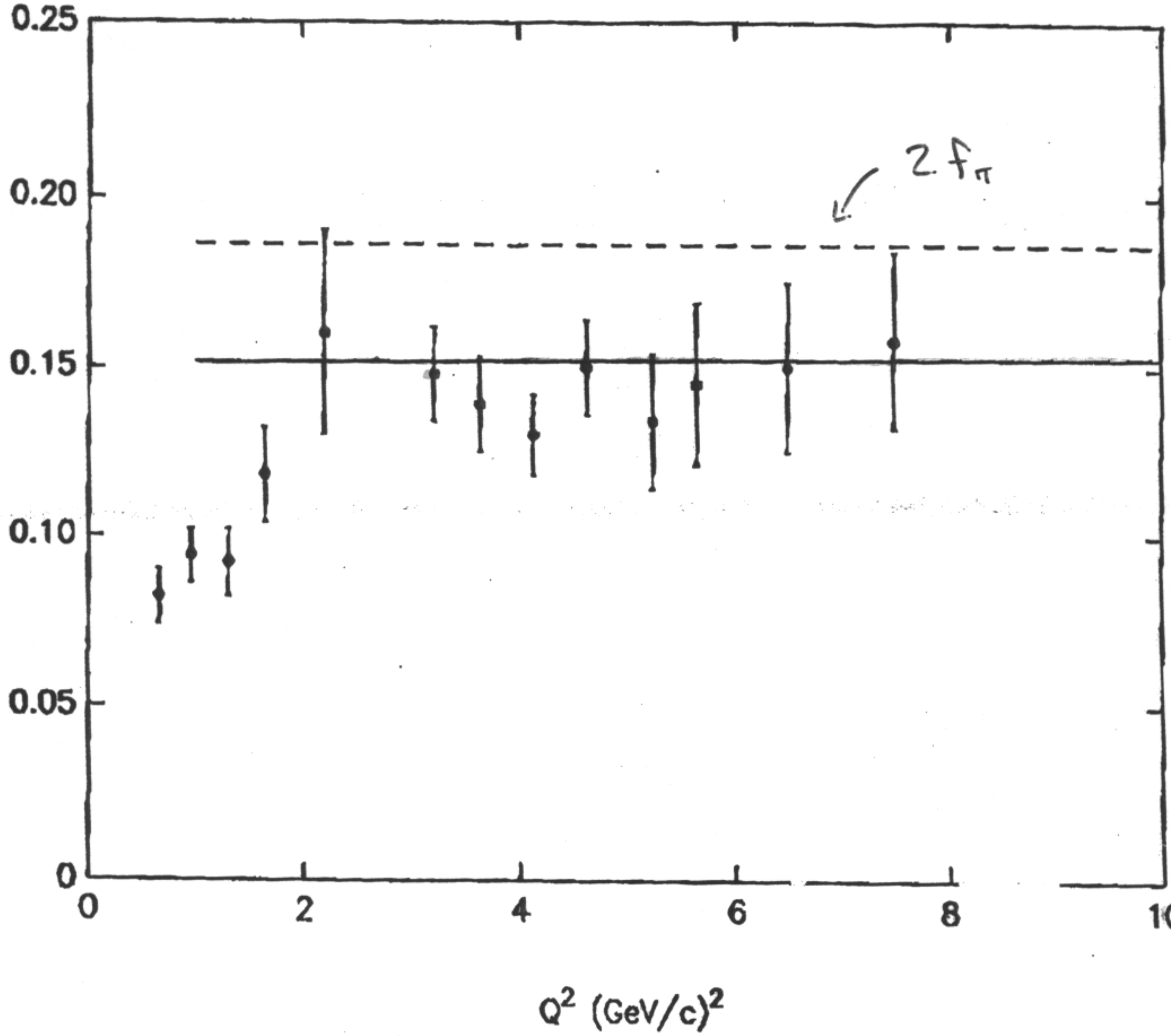
$$\phi_\pi(x, \tilde{Q}) = \int^{\tilde{Q}} \frac{d^2k_\perp}{16\pi^3}\, \psi^{(\tilde{Q})}_{q\bar{q}}(x, k_\perp)$$

$$\int_0^1 dx\; \phi_\pi(x, Q) = \frac{f_\pi}{2\sqrt{3}}$$

SJB
Lepage

$$* \quad \phi = \phi_{asympt} = \sqrt{3}\, x(1-x)\, f_\pi$$

$$Q^2 F_{\pi\gamma}(Q^2) = 2 f_\pi \left[1 - \frac{5}{3\pi}\, \alpha_V(e^{-3} Q^2) \right]$$



C.LBC

$$\boxed{\gamma^* \gamma^* \to \text{resonances}}$$

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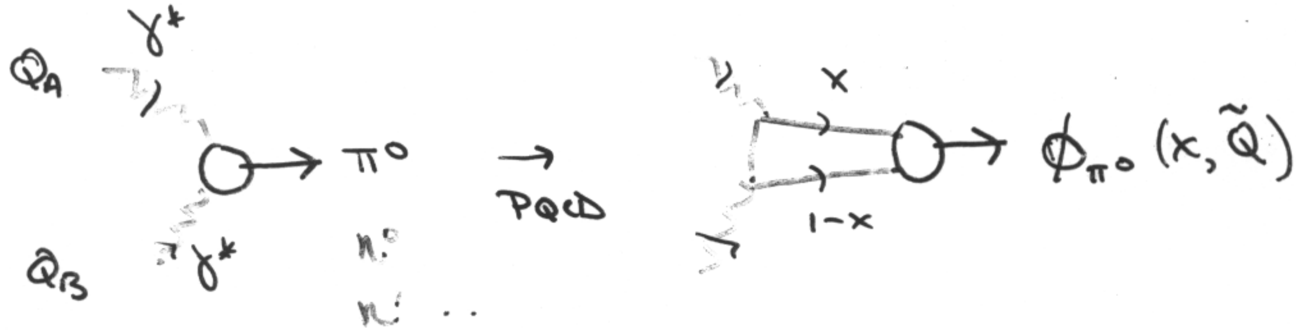
G.P. Lepage



S. Ong : study shape of $\phi_{\pi^0}(x, \tilde{Q})$

from dependence in $\omega = \dfrac{Q_A^2 - Q_B^2}{Q_A^2 + Q_B^2}$

$$F_{\gamma^*\gamma^*\pi^0}(Q_A^2, Q_B^2) = \frac{2 f_\pi}{\bar{Q}^2} G(\omega)$$

$$\bar{Q}^2 = (Q_A^2 + Q_B^2)/2$$

e.g. $\phi_\pi^{asy}(x) = \sqrt{3}\, f_\pi\, x(1-x)$

$$F_{\gamma^*\gamma^*\pi^0} \to \begin{cases} \dfrac{2 F_\pi}{Q_A^2} & Q_B^2 = 0 \\[2ex] \dfrac{2 f_\pi}{3 Q_A^2} & Q_B^2 = Q_A^2 \quad \text{OPE} \end{cases}$$

(L.O.)

Large p_T: $\gamma\gamma \to$ hadron pairs

PQCD fixed-angle scaling

$$\boxed{\frac{d\sigma}{dt}(\gamma\gamma \to H_1 H_2) \sim \frac{1}{s^{n-2}} F(\theta_{cm})}$$

dimensional counting rule:

$$n = 2 + n_1 + n_2$$

↖ # elementary fields

$$\frac{d\sigma}{dt} \sim \frac{1}{s^4} f(\theta_{cm})$$ meson pairs

$$\sim \frac{1}{s^6} f(\theta_{cm})$$ baryon pairs

$$\lambda_1 + \lambda_2 = 0$$ hadron helicity conservation

* Normalization, θ_{cm}-dependence
  $\Rightarrow$ QCD subprocesses
  hadron distribution amplitudes

* Scale-breaking: α_s^n. anom. dimensions

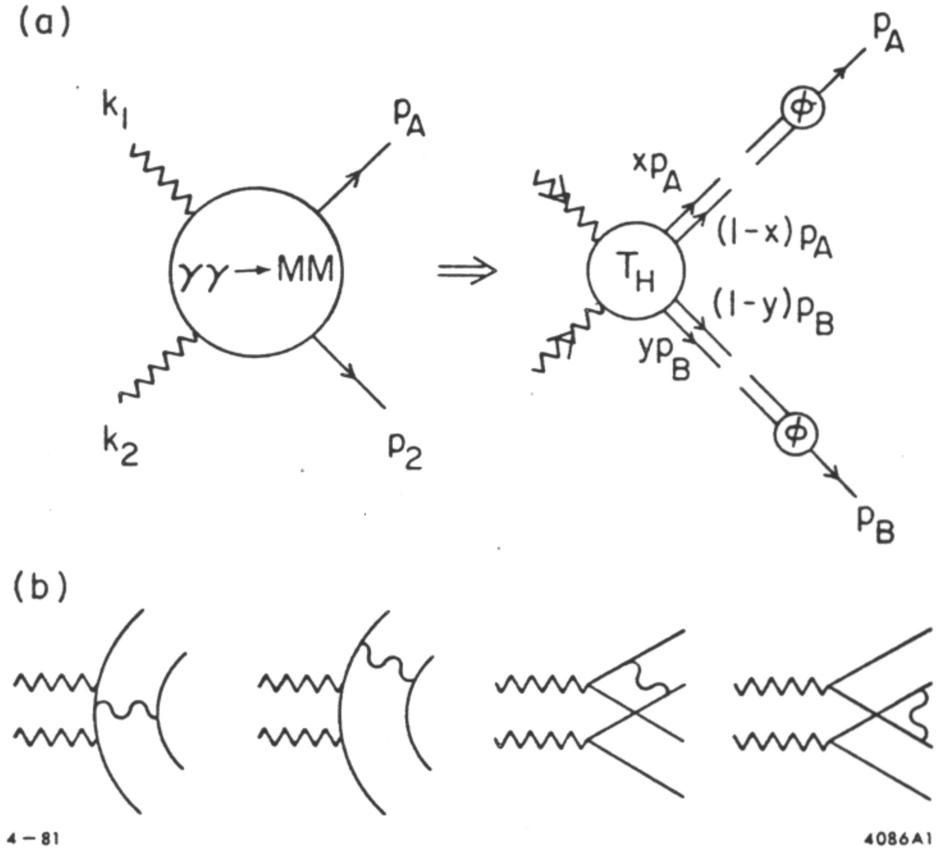
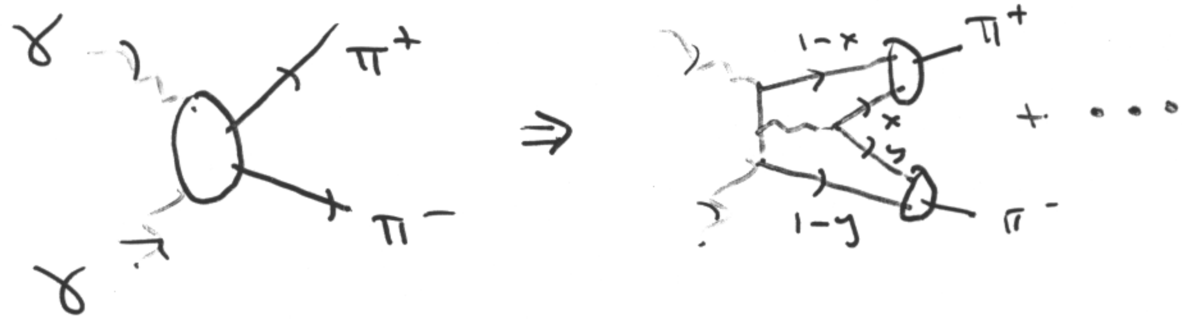


Fig. 1

Exclusive Hard Photon-Photon Processes

$\Rightarrow$ test QCD at amplitude level

SJB
G.P. Lepage
Radyushkin



$$* \quad \mathcal{M}_{\gamma\gamma\to\pi^+\pi^-} = \int_0^1 dx \int_0^1 dy \, T_H^{\gamma\gamma\to q\bar{q}\, q\bar{q}}(x, y, \theta_{cm}, P_T) \, \phi_\pi(x, P_T) \, \phi_\pi$$

Factorization theorem

$$* \quad T_H = \frac{\alpha \alpha_s}{P_T^2} f(\theta_{cm})$$

PQCD
leading order

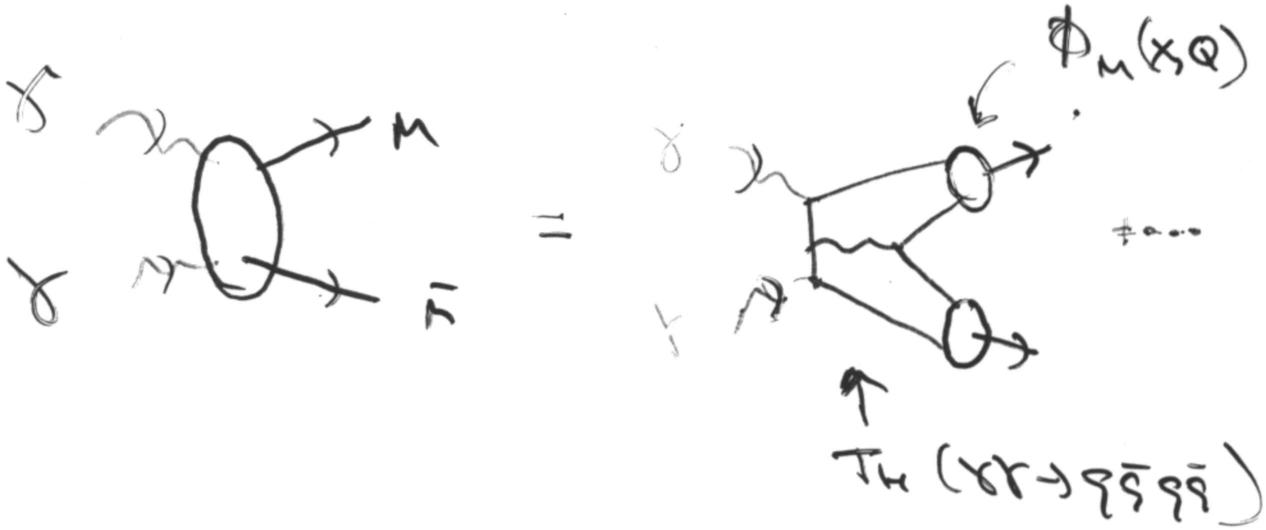
distribution amplitude

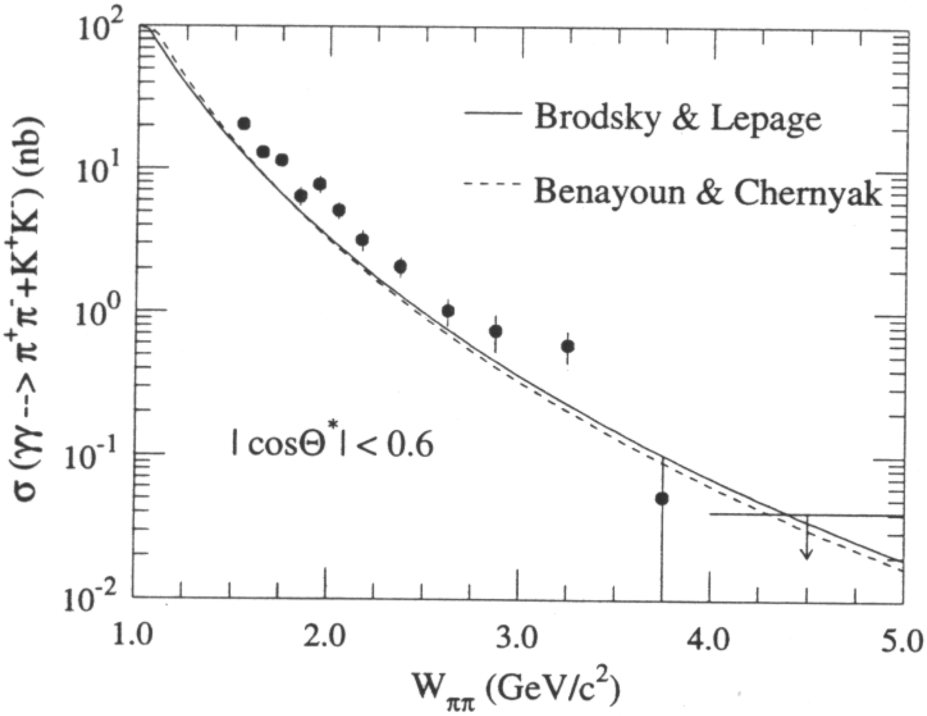
$$\phi_\pi(x, Q) = \int^Q d^2k_\perp \, \psi_\pi^{q\bar{q}}(x, \vec{k}_\perp)$$

non-pert.

$$* \quad \frac{\partial}{\partial \ln Q} \phi_\pi(x, Q) = \int_0^1 dy \, V(y, x) \, \phi_\pi(y$$

$\boxed{\sigma_{\gamma\gamma \to K^+K^-,\ \pi^+\pi^-}}$





$\alpha_V \sim$ const ?
at low scale

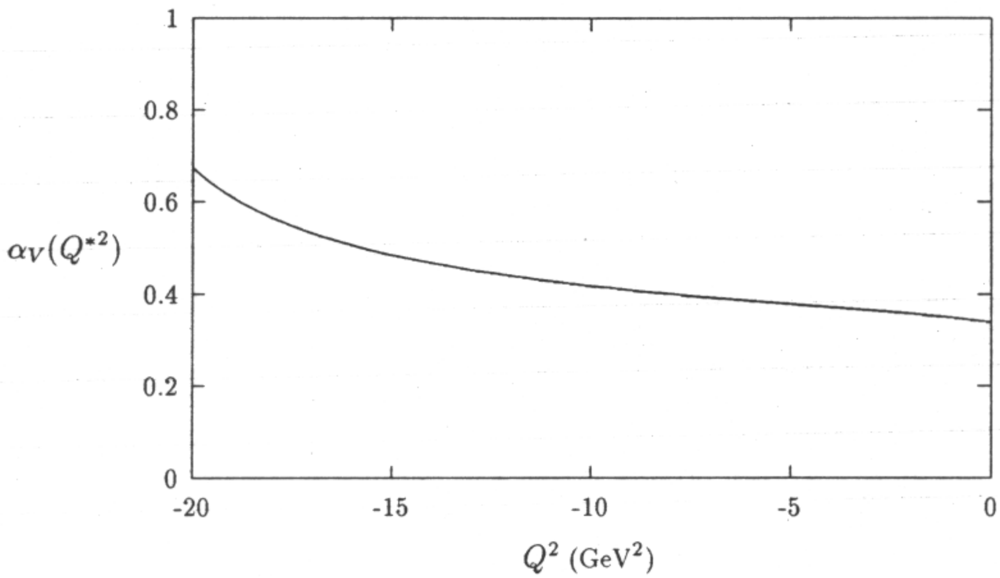
SJB, Ji, Pang, Robertson

CLEO data

$\frac{1}{s^4} f(\theta_{cm})$

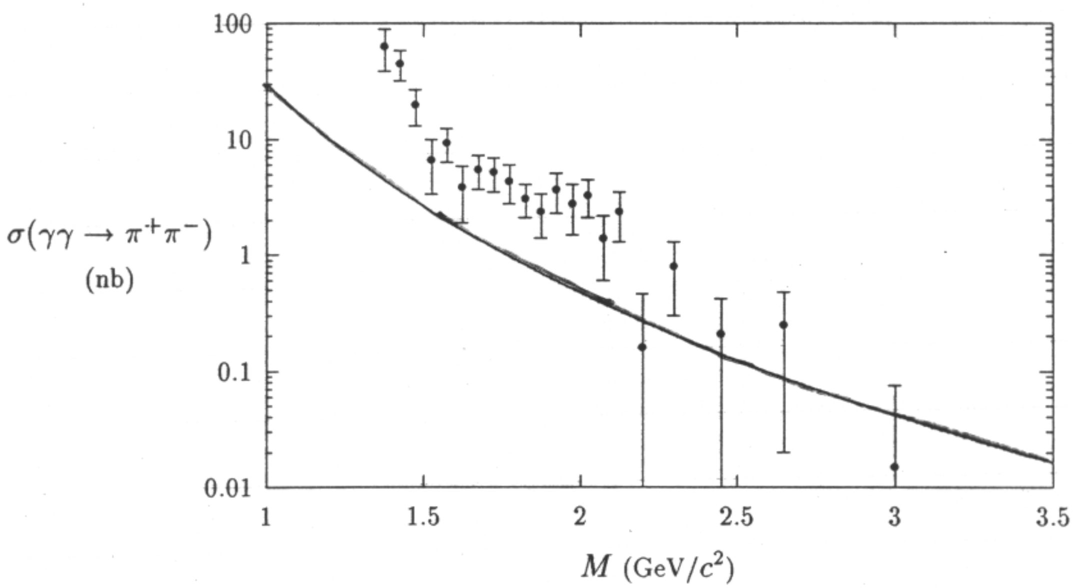
test leading twist scaling of PQCD

normalization from $F_\pi(s)$.



model for timelike α_V

SJB, Ji; Pang, Robertson



Leading order PQCD prediction $\phi_\pi = \phi_{asympt}$

H. Aihara et al PRL 57, 404 (1986)

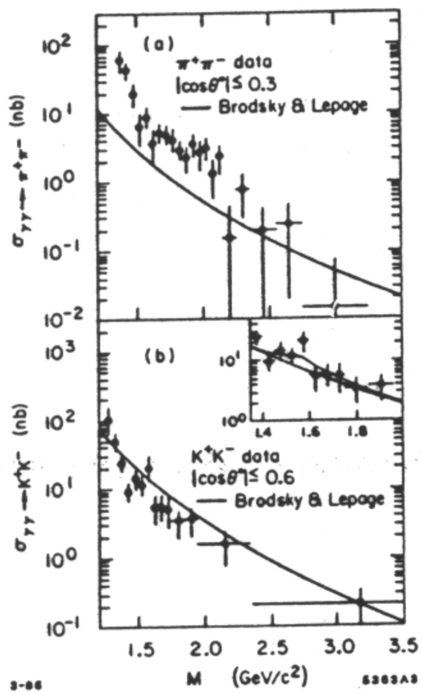
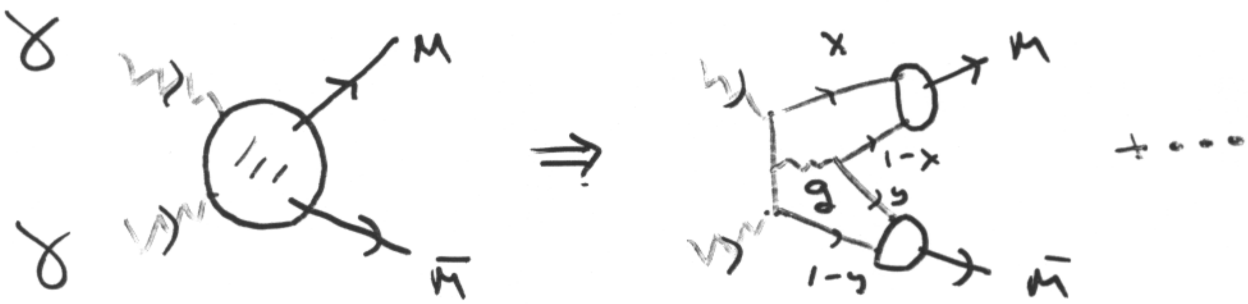


Figure 31. Comparison of $\gamma\gamma \to \pi^+\pi^-$ and $\gamma\gamma \to K^+K^-$ meson pair production data with the parameter-free perturbative QCD prediction of Ref. 82. The theory predicts the normalization and scaling of the cross sections. The data are from the TPC/$\gamma\gamma$ collaboration.[55]

Issues in $\gamma\gamma$ Hard-Scattering

Exclusive Processes

SJB
G.P. Lepage



* $$\frac{d\sigma}{dt} = \frac{\alpha^2 \alpha_s^2}{s^4} F\left(\frac{p_T^2}{s}, \ln p_T\right)$$

$(\lambda_M + \lambda_{\bar{M}} = 0$

* $$\frac{\frac{d\sigma}{dt}(\gamma\gamma \to M\bar{M})}{\frac{d\sigma}{dt}(e^+e^- \to M\bar{M})} \cong F_{M\bar{M}}(\theta_{cm})$$

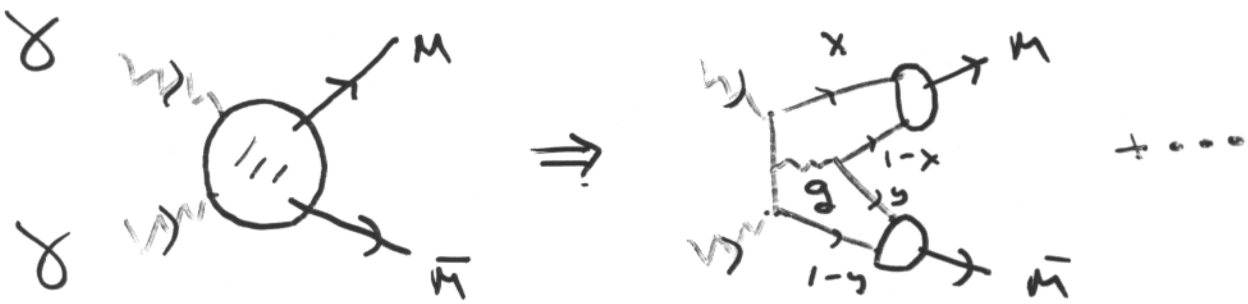
$$\Rightarrow \phi_M(x, \tilde{Q})$$

* $\alpha_s(\mu) \Rightarrow \alpha_V(Q^*)$ Commensurate Scale Relns

Issues in $\gamma\gamma$ Hard-Scattering

Exclusive Processes

SJB
G.P. Lepage



$*$ $$\frac{d\sigma}{dt} = \frac{\alpha^2 \alpha_s^2}{s^4} F\left(\frac{p_T^2}{s}, \ln p_T\right)$$

$(\lambda_M + \lambda_{\bar{M}} = 0$

$*$ $$\frac{\frac{d\sigma}{dt}(\gamma\gamma \to M\bar{M})}{\frac{d\sigma}{dt}(e^+e^- \to M\bar{M})} \cong F_{M\bar{M}}(\theta_{cm})$$

$$\Rightarrow \phi_M(x, \tilde{Q})$$

$*$ $\alpha_s(\mu) \Rightarrow \alpha_V(Q^*)$ Commensurate Scale Relns

[illegible]

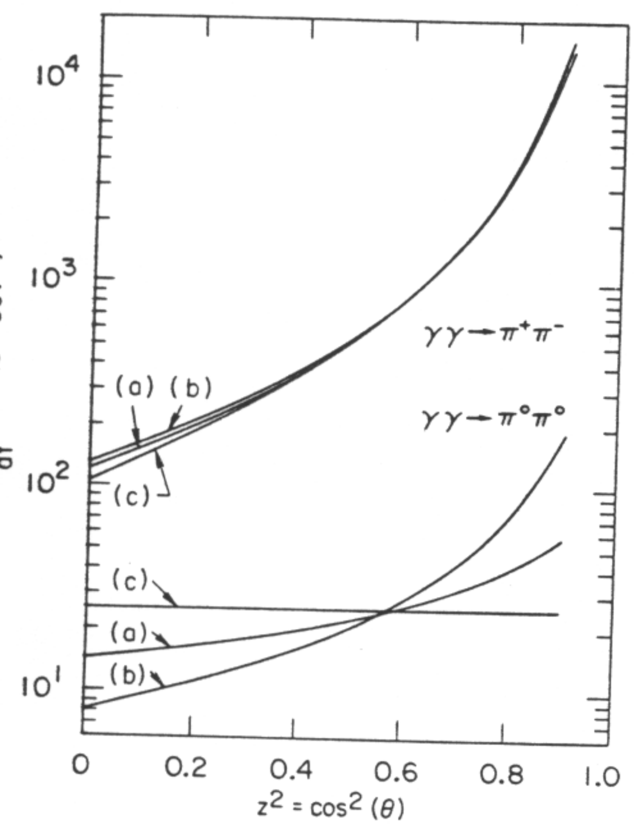


Fig. 13. Perturbative QCD predictions for $\gamma\gamma \to \pi\pi$ at large momentum transfer. Predictions for other helicity-zero mesons only differ in normalization. The curves (a), b) and (c) correspond to the three distribution amplitudes described in the text.

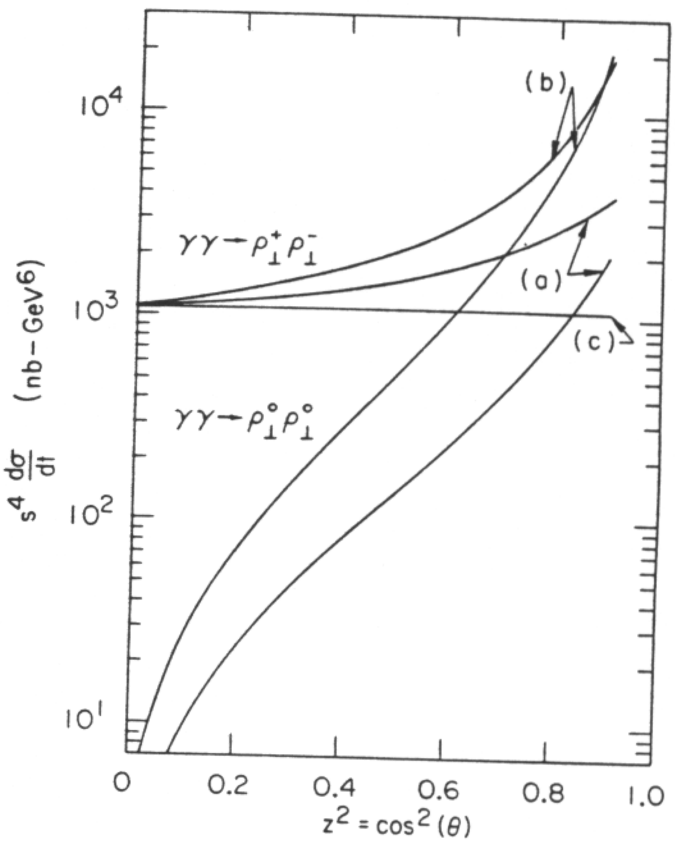
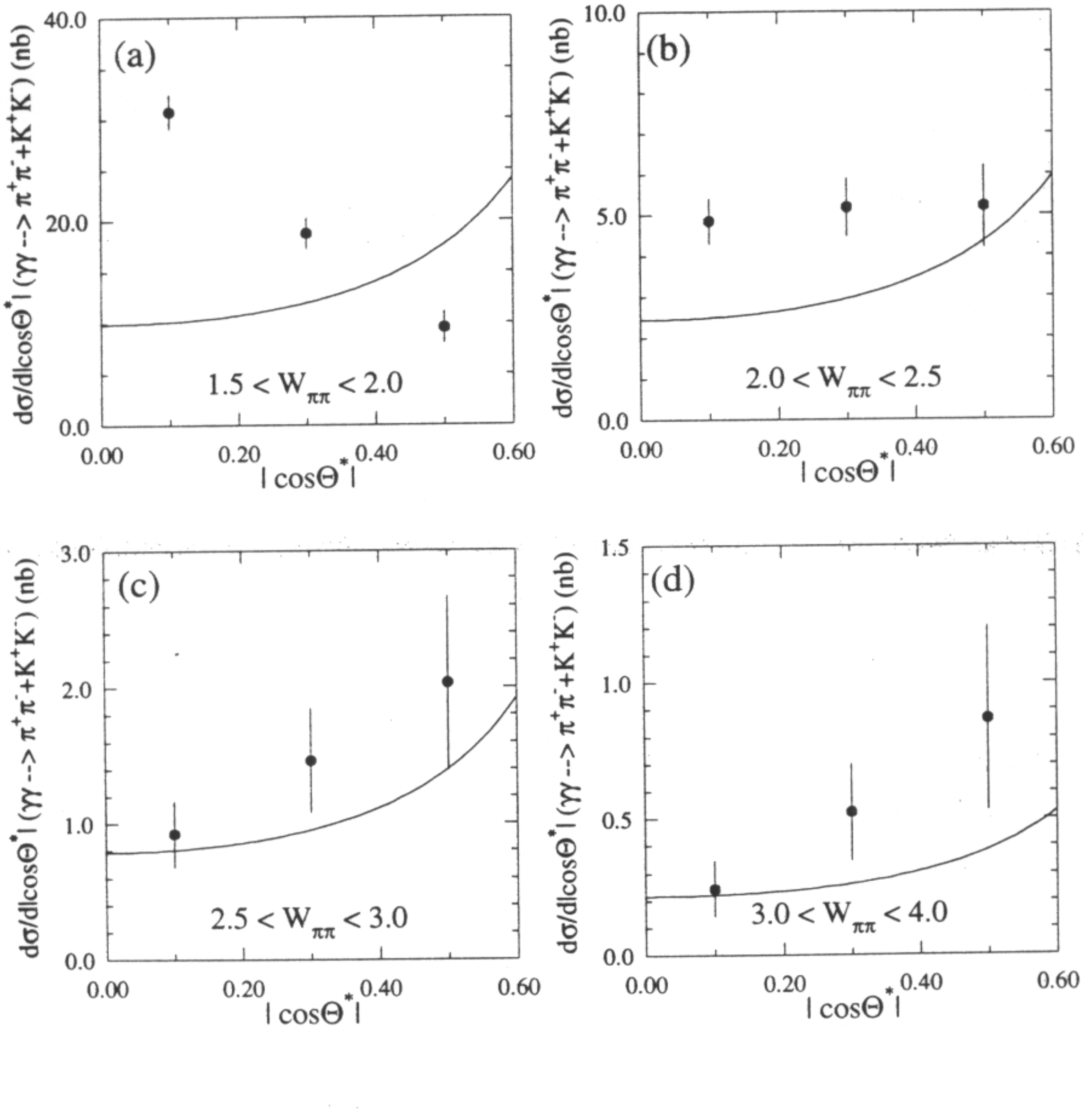


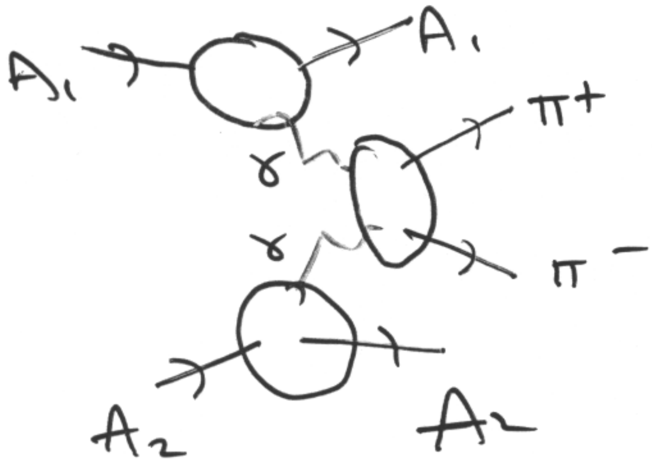
Fig. 14. Perturbative QCD prediction for $\gamma\gamma \to \rho_T\rho_T$ at large momentum transfer, corresponding to the normalization and choices of ϕ_ρ described in the text.



(a)
1.5 < W_ππ < 2.0
(b)
2.0 < W_ππ < 2.5
(c)
2.5 < W_ππ < 3.0
(d)
3.0 < W_ππ < 4.0
dσ/d|cosΘ*| (γγ --> π+π- + K+K-) (nb)
| cosΘ* |
0.00
0.20
0.40
0.60
40.0
20.0
0.0
10.0
5.0
3.0
2.0
1.0
1.5
0.5

Coherent Production of Continuum Pairs at RHIC

$P_T(\pi^+\pi^-) < 30$ MeV



+ pomeron, odderon contributions

+ final-state ints.

$$R = \frac{\frac{d\hat{\sigma}}{dk_\perp^2}(\pi^+\pi^-)}{\frac{d\hat{\sigma}}{dk_\perp^2}(\mu^+\mu^-)} \to \frac{1}{k_\perp^4} f(\theta_{cm})$$

PQCD scaling
SJB + Farrar
SJB + Lepage
MIT

Pomeron, odderon contributions fall faster with $k_\perp$!

$$R \Rightarrow \frac{1}{k_\perp^6}, \quad \frac{1}{k_\perp^8}, \quad \frac{1}{k_\perp^{12}}$$

$\gamma + \mathrm{Pom} \to \pi^+\pi^-$ Pom + Pom   Odd + T

$$\boxed{R_{\gamma\gamma\to H\bar{H}} = \frac{\frac{d\sigma}{dt}(\gamma\gamma\to H\bar{H})}{\frac{d\sigma}{dt}(\gamma\gamma\to\mu^+\mu^-)}}$$

* Fundamental tests of PQCD

$$R_{\gamma\gamma\to H\bar{H}} = \left(\frac{1}{k_\perp^2}\right)^{2n_H-2} F_{\gamma\gamma\to H\bar{H}}(\theta_{cm})$$

from: $\frac{d\sigma}{dt}(AB\to CD) = \frac{1}{s^{n_{TOT}-2}} F(\theta_{cm})$

$R_{\gamma\gamma\to H\bar{H}}$ measured at CLEO

$H = \pi, k, \Lambda, \Sigma$

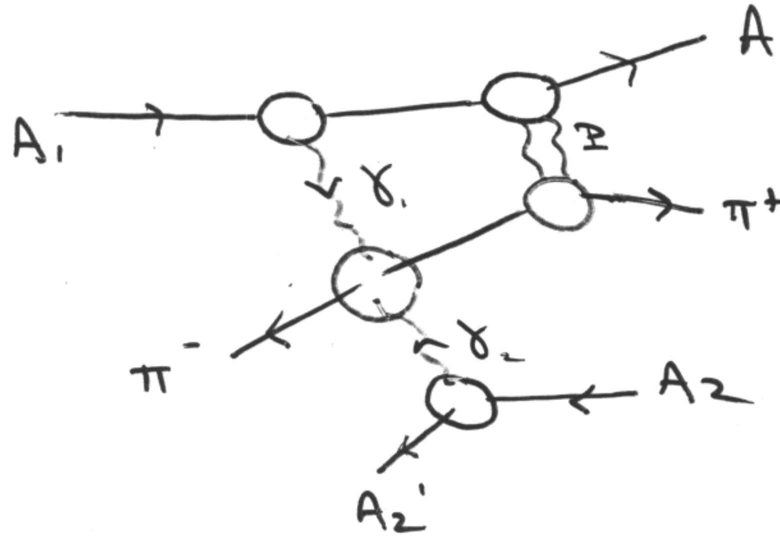
RHIC: Deviations from Pomeron, Odderon

+ Final State Interactions reduced by color transparency

Final - State Interactions

in nucleus - nucleus collisions

Cahn
Jackson



* Compare with $e^+e^- \to \pi^+\pi^- e^+e^-$

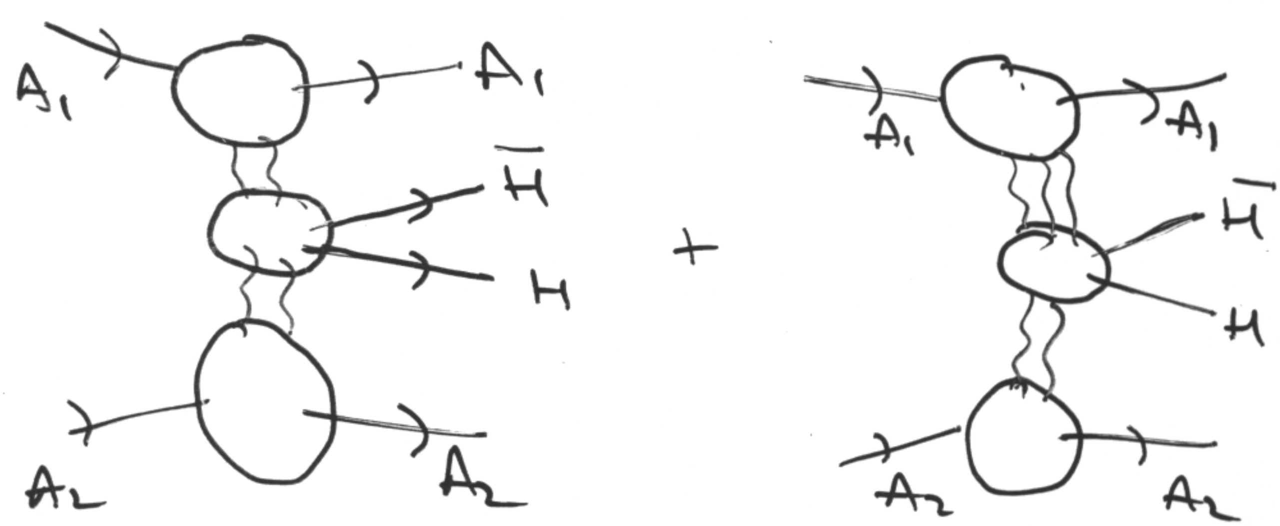
* control by kinematics : out of plane vs in plane

* at large p_T

  FSI suppressed by color transparence

SJB + Lepage
A. Mueller

Hadron Pair Asymmetry
sensitive to Pomeron / Odderon Interference



(Also γ exchange.)

Analysis by SJB, Rathsman, Merino

$$A = \frac{\sigma(E_H > E_{\bar{H}}) - \sigma(E_H < E_{\bar{H}})}{+}$$

Analysis Tools for $A_1 A_2 \to H\bar{H}\, A_1 A_2$

Z, A dependence : distinct for γ vs Pom, Odd.

$k_\perp$ dependence : softer for Pomeron Odderon.

lepton signal normalizes $\gamma\gamma$

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

$e^+e^- \to H\bar{H}\, e^+e^-$

at CLEO

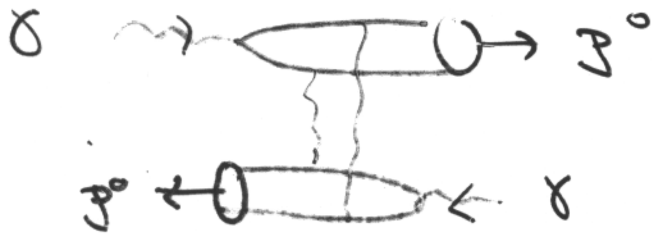
$b_\perp$ dependence : range of photon, photon

Diffractive high energy processes

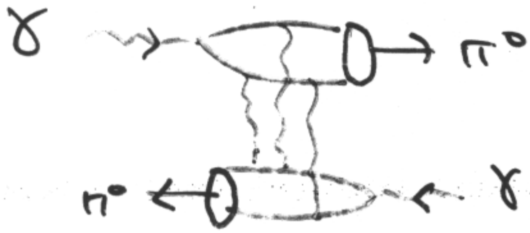
Klein

$$\gamma^* \gamma^* \to \rho^0 \rho^0$$

Ginzburg
Serbo
Panfil

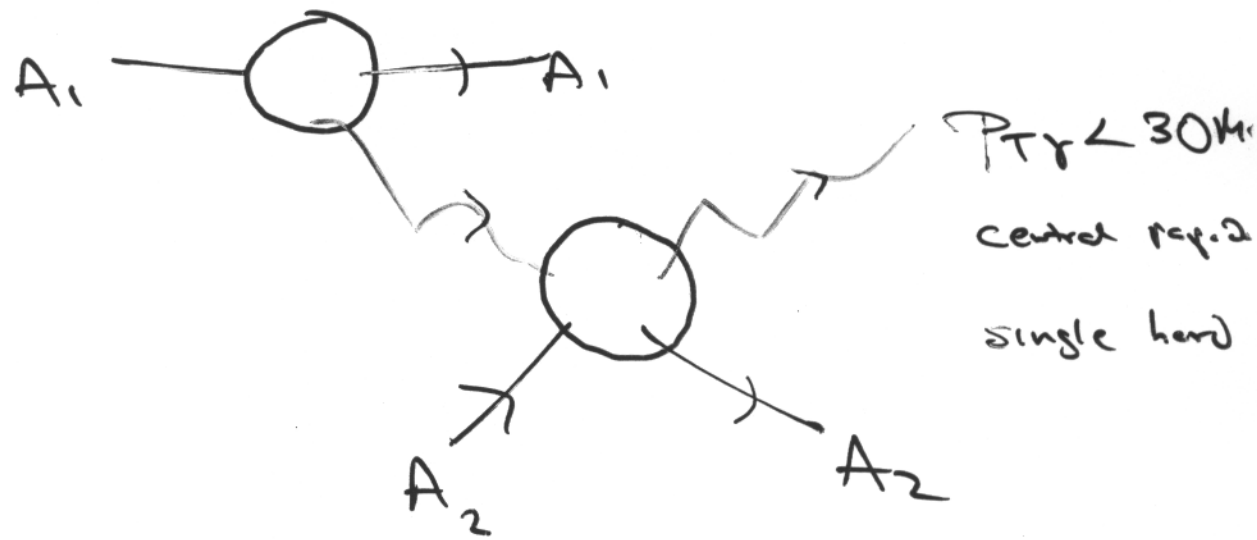


pomeron exchange



odderon exchange

Compton Process at RHIC



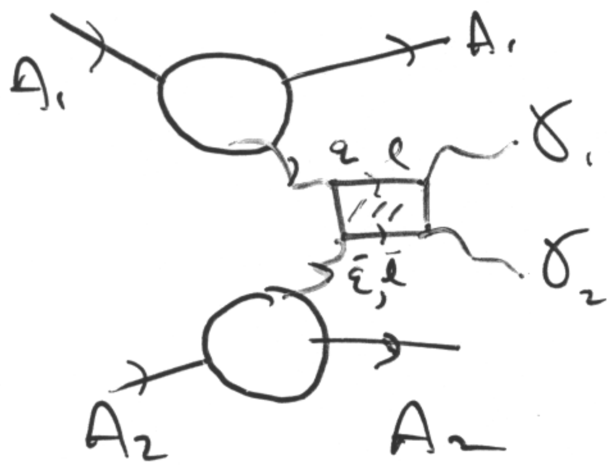
$$\sigma \sim \frac{Z_1^2 \, Z_2^4 \, \alpha^3}{M_2^2} \int \frac{db_\perp^2}{b_\perp^2}$$

(low energy Thomson scattering contribution.)

$$\sigma \sim \frac{Z_1^2 Z_2^4 \alpha^3}{M_2^2} \log S/M_N^2$$

Background from odderon bremsstrahlung

Study Light-by-Light Scattering at RHIC



$\vec{P}_T = \vec{k}_{\perp 1} + \vec{k}_{\perp 2}$

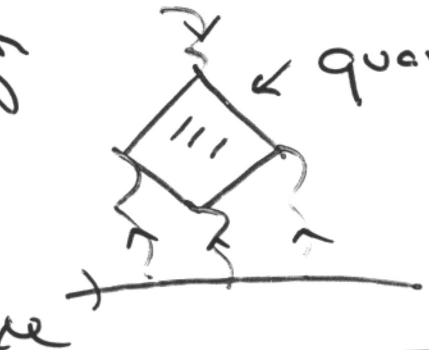
$P_T < 30$ MeV

$$\frac{d\hat{\sigma}}{dk_\perp^2} \sim \frac{1}{k_\perp^4}\, f(\theta_{cm})_{\gamma\gamma\to\gamma\gamma}$$

Important for

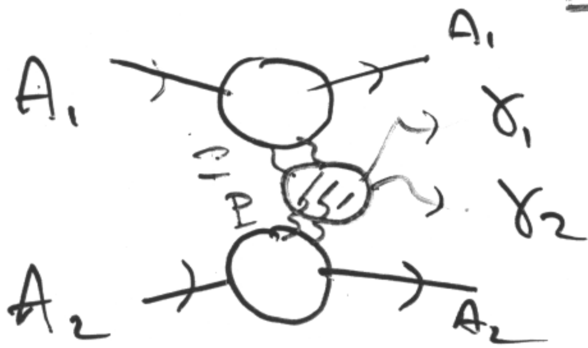
$(g-2)_\mu^{had}$

at order α^3



$k_\gamma^2 \sim O(m_\pi^2)$

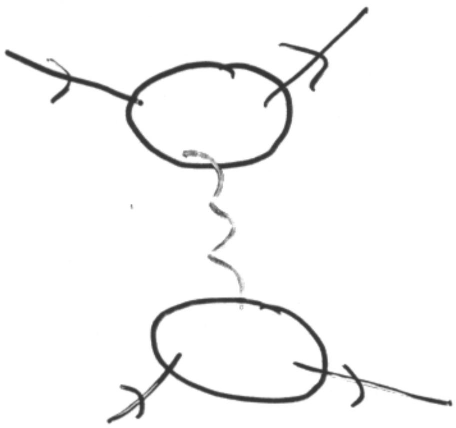
Background



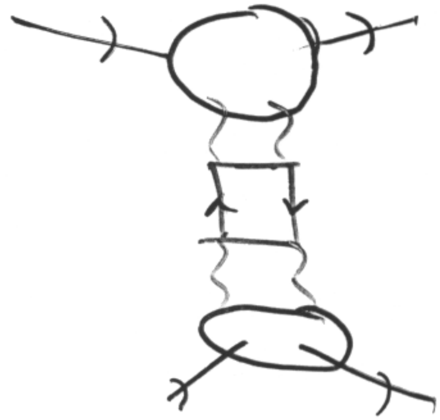
$$\frac{d\hat{\sigma}}{dk_\perp^2} \sim \frac{1}{k_\perp^8}\, f(\theta_{cm})_{PP\to\gamma\gamma}$$

Light-by-Light correction to QED Potential (Heavy N.R. Nuclei)

V :

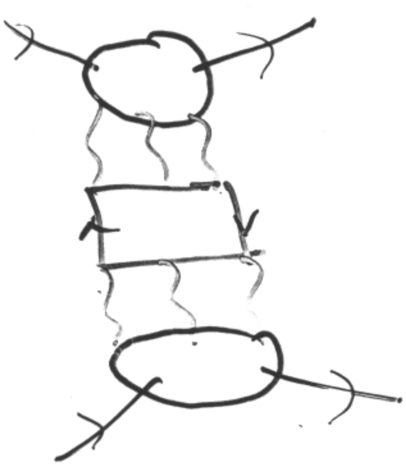


+



$$\frac{Z_1 Z_2 \alpha}{q^2} + \frac{Z_1^2 Z_2^2 \alpha^4}{m_\ell^2}$$

+



$$\frac{Z_1^3 Z_2^3 \alpha^6}{m_\ell^2} + \cdots$$

all terms important at large

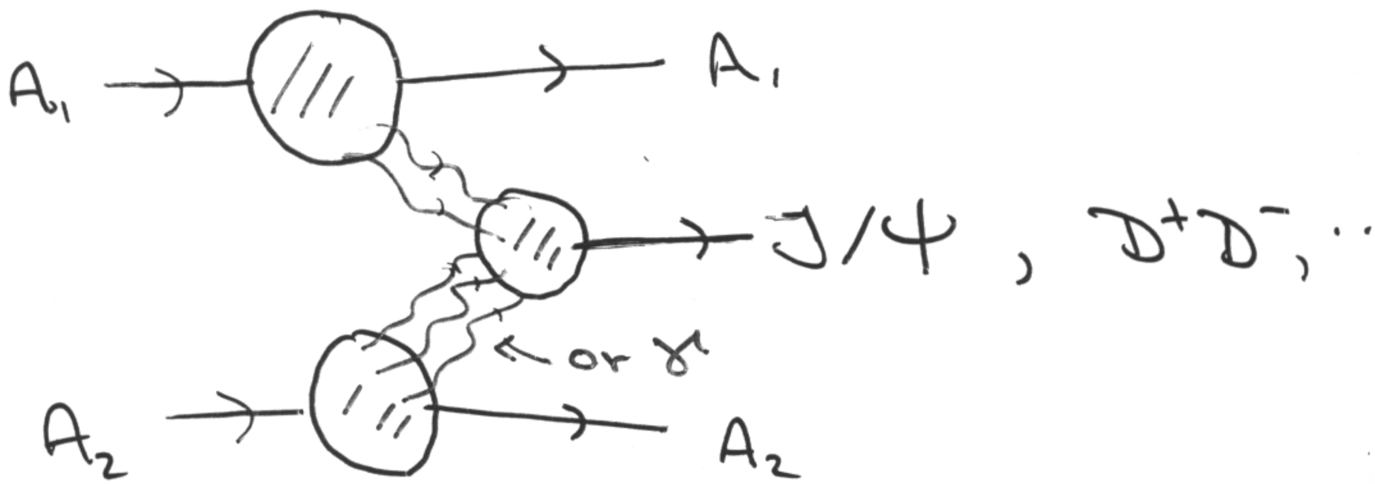
$$V = \frac{Z_1 Z_2 \alpha}{q^2}\left[1 + \frac{\alpha q^2}{m_\ell^2} F(Z_1\alpha, Z_2\alpha)\right.$$

Charm at Threshold

Coherent nuclear production

gives $E_\gamma^{cm} \lesssim 3$ GeV, $\sqrt{s} \lesssim 6$ GeV

or $E_{pom}^{cm} \lesssim 3$ GeV



$P_T(J/\psi) < 30$ MeV

Explore production mechanism

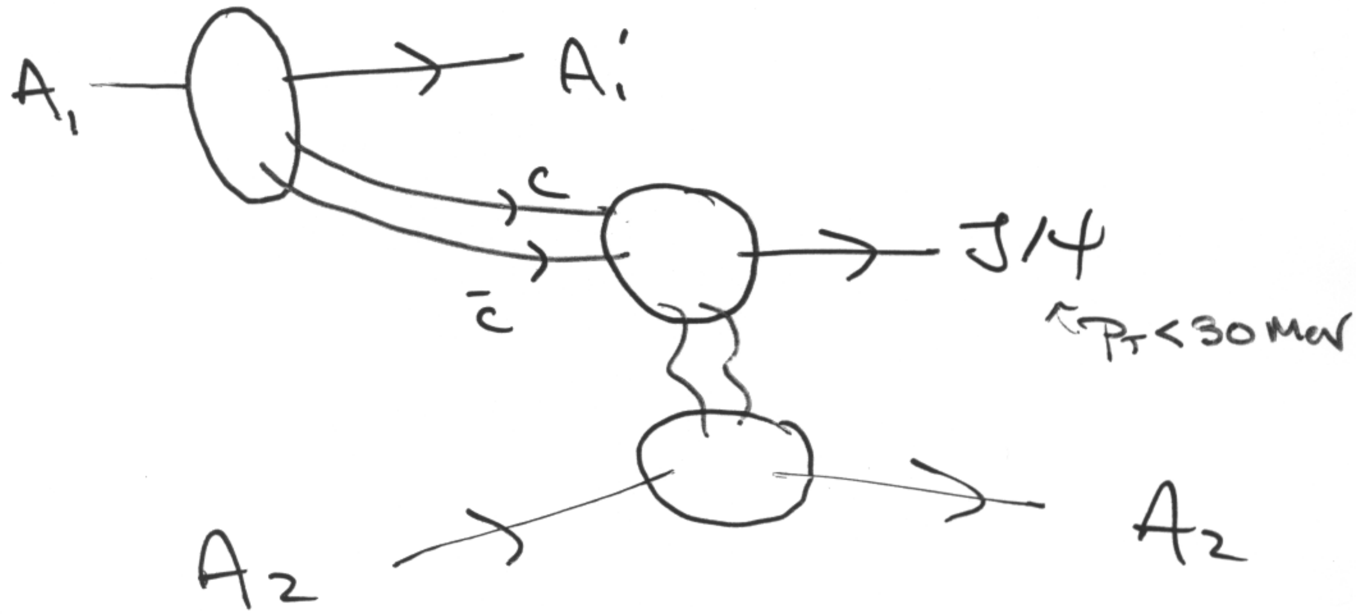
Asymmetry for D^+D^- distributions

— non-perturbative physics

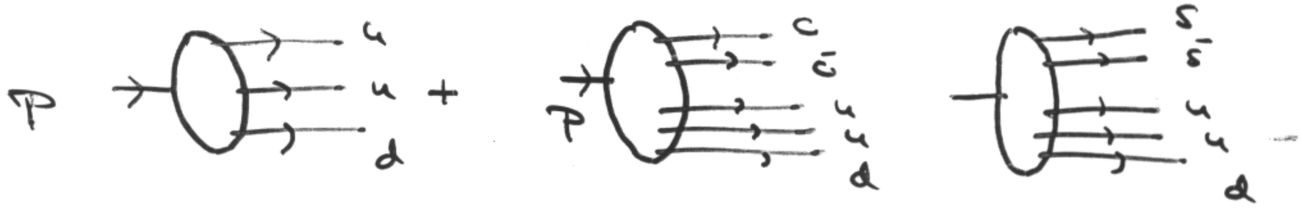
Nuclear Dependence

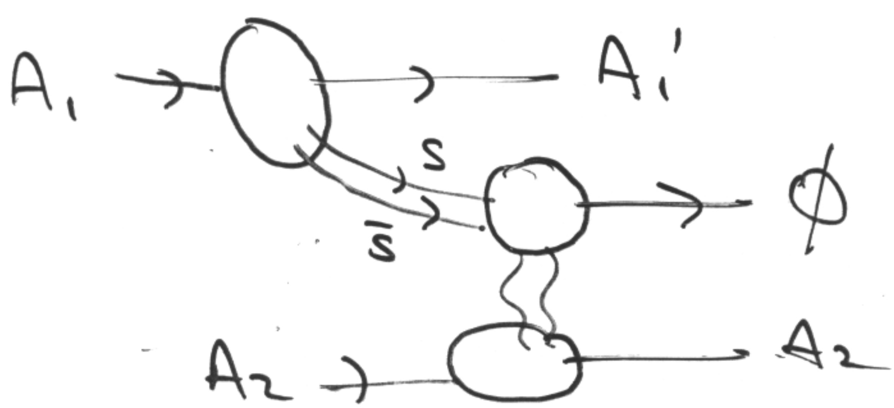
Coherent Intrinsic Heavy Quarks

New production mechanism

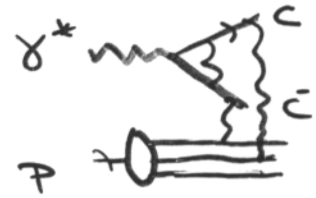


* From higher Fock states of nucleon



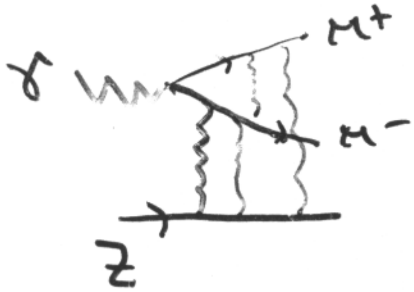


Dynamics of Charm Production near threshold



* - Strong Initial and Final State Interactions at low relative velocity

* QED analog: (Schwinger, Sommerfeld, Fermi



$$\sigma = \sigma_{BH} \frac{X^+}{1+e^{+X^+}} \frac{X^-}{1-e^{-X^-}} \frac{X}{1-e^{-}}$$

$$X^{\pm} = \frac{\pi Z \alpha}{\beta^{\pm}} \qquad X = \frac{\pi\alpha}{\beta}$$

* QCD: $\dfrac{X}{1-e^{-X}}$, $X = \frac{4}{3}\pi \dfrac{\alpha_V(\beta^2 m^2)}{\beta}$

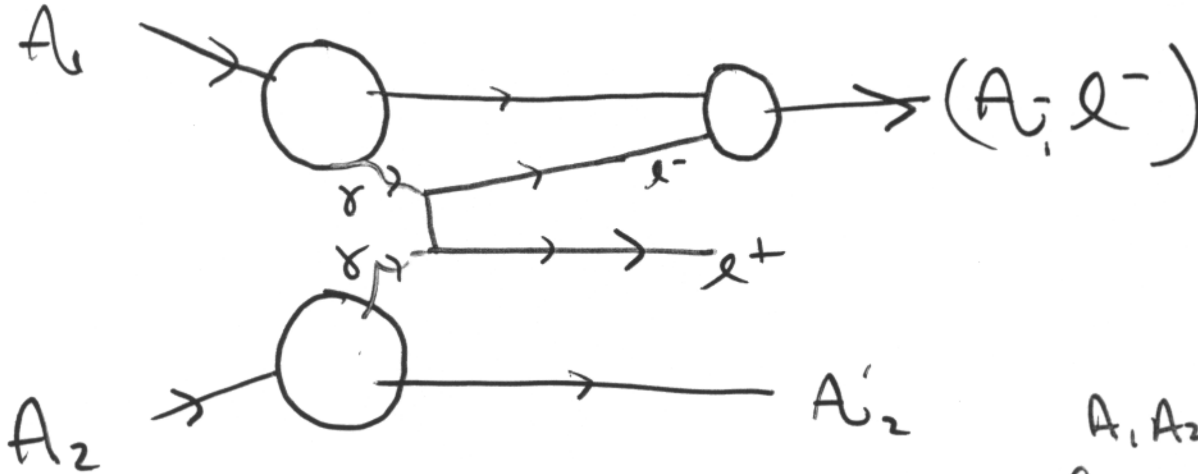
* strong distortions of Born cross section, angle

* Newton's Law of Inertia: look at D, D^*

* Relation of $\gamma^* p \to J/\psi\, p$, $c X$ to gluon dist complicated

* Intrinsic Charm, ANN

Capture Processes at RHIC



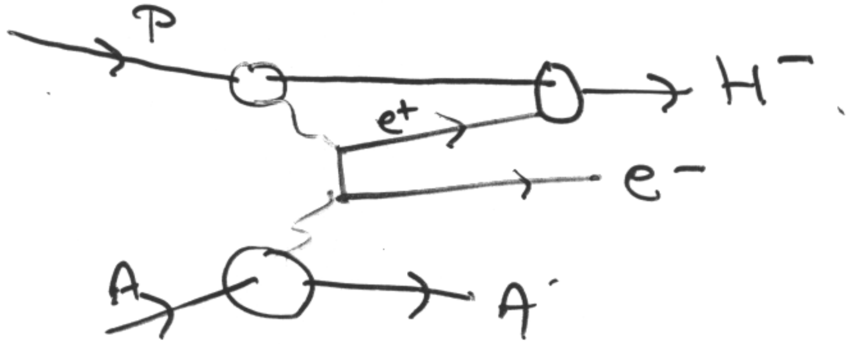
$A_1 A_2 \to (A_1 e^-) \ldots$
limits $\mathcal{L}$
at RHIC

$\ell = e, \mu, \tau$

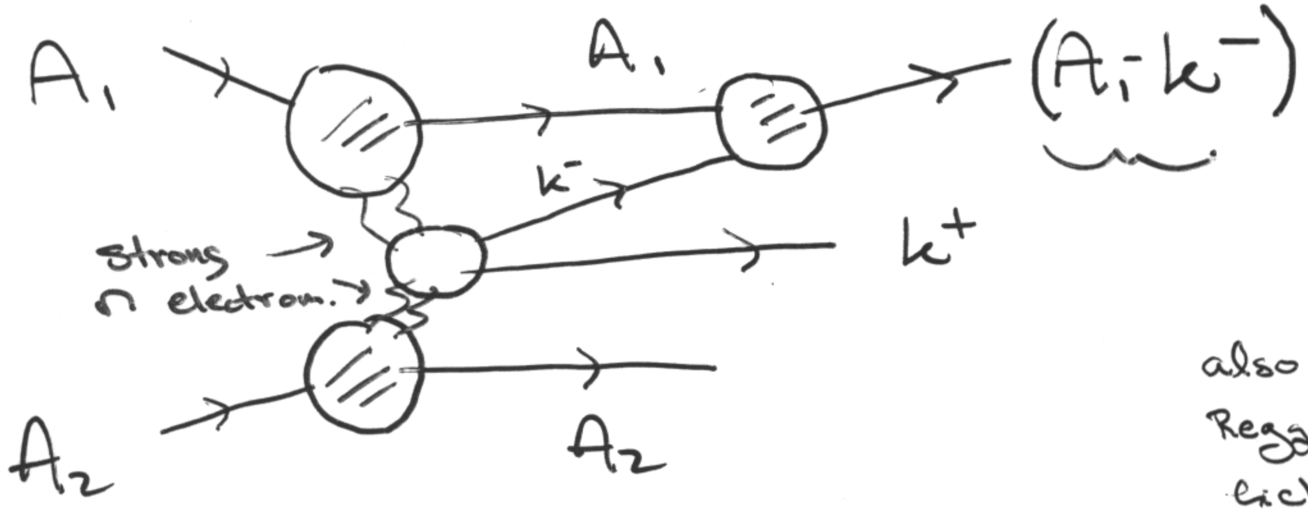
* Detect single lepton at $p_T < 30$ MeV

Similar to <u>antihydrogen</u> production
at CERN, FermiLab

SJB
C. Munger
I. Schmidt



Exotic Capture Processes at RHIC



also Reggeon exchange !

* Observe single hadron at $p_T < 30$ Me

  $H = K^\pm, \pi^\pm, \Lambda, \bar{\Lambda}, \Sigma, \bar{\Sigma}$

  $p, \bar{p}, D^\pm, \Lambda_c, \bar{\Lambda}_c \ldots$

* Observe coalesced system $(A_1\text{-}\bar{H})$ with distinct mass, charge in forward spectrometer.

* Detect exotic hypernuclei !

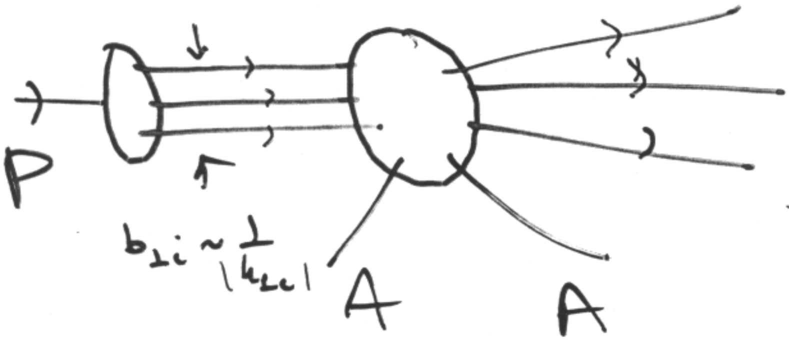
Diffractive Tri-Jet Production at RHIC

$$pA \to JJJ\,A'$$

Bertsch, SJB
Goldhaber, Gunion

Frankfurt, Miller
Strikman

$\pi A \to JJ\,A$ recently measured by E791 at FNAL.



$P_T = \sum k_\perp < 30$

$|k_\perp^i| > 1$ GeV

1. Color Transparency, Coherence

$$\frac{d\sigma}{dp_T^2} \propto A^2 \quad \text{at} \quad p_T \to 0$$

2. Measure $\psi^{LC}_{qqq/p}(x_i, \vec{k}_{\perp i})$

$$\sum x_i = 1\,, \quad \sum \vec{k}_{\perp i} = 0$$

Fundamental w.f. of Proton!

Color Transparency

– fundamental feature of gauge theory

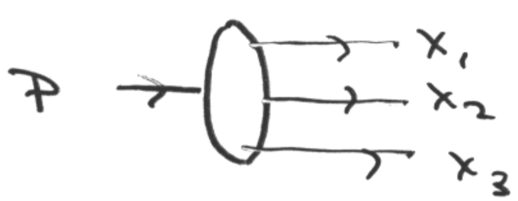
Quantum field theory: $|\Psi\rangle = \sum_n \psi_n |n\rangle_0$

hadron is fluctuating system

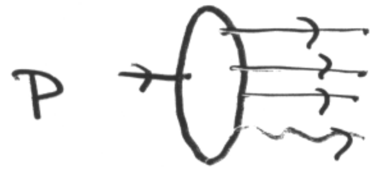
* variable size

* variable Fock state number

$\tau = t + z$ fixed $\qquad A^+ = 0$



$$\psi_{qqq}(x_i, \vec{k}_{\perp i}, \lambda_i)$$

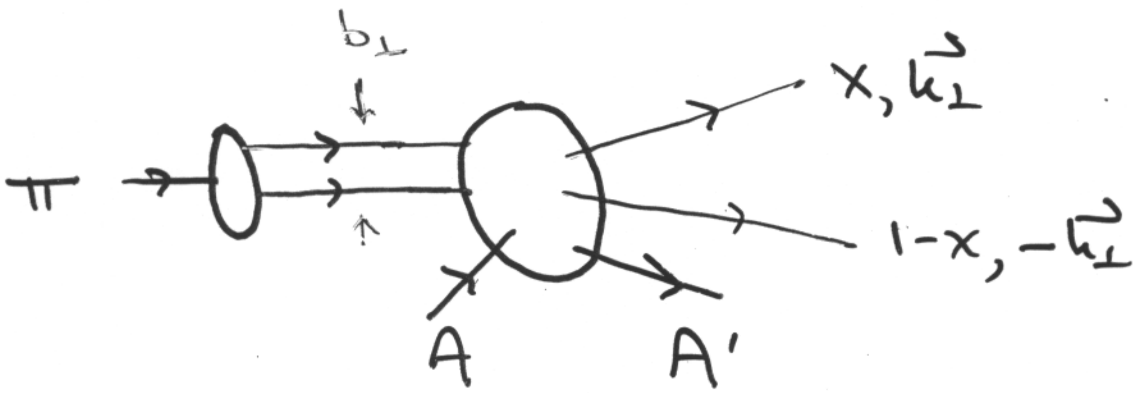


$$\psi_{qqqg}(x_i, \vec{k}_{\perp i}, \lambda_i)$$

Color singlet $\quad B = 1 \quad Q = 1 \quad J_z = \pm 1/2$

$x_i = \frac{k_i^0 + k_i^z}{p^0 + p^z} \qquad \sum x_i = 1, \quad \sum \vec{k}_{\perp i} = 0$

$\boxed{\text{Test of Color Transparency and Measurement of } \psi_\pi(x, k_\perp)}$



* "Nuclear Filter"

Small color-singlet components pass

large components absorbed

* Diffractive production of di-jets

nucleus left <u>intact</u>

* Jet distributions measure

$$\psi_\pi(x, \vec{k}_\perp)$$

G. Bertsch
J. Gunion
SJB F. Goldhaber

Frankfurt
Miller
Strikman

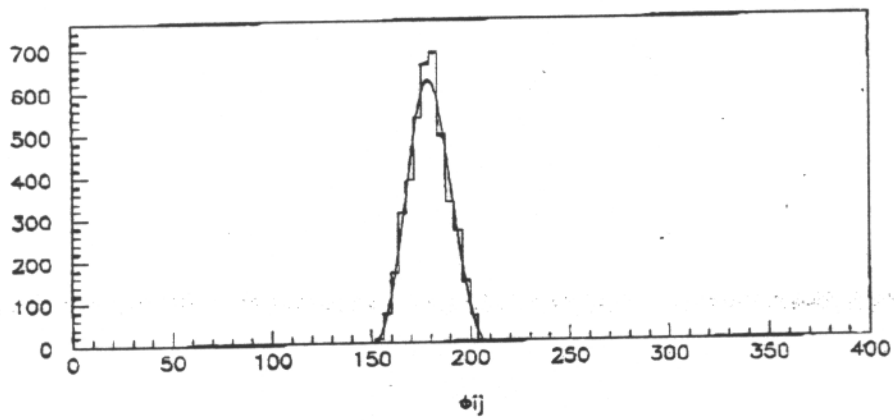
E791 Prelim.

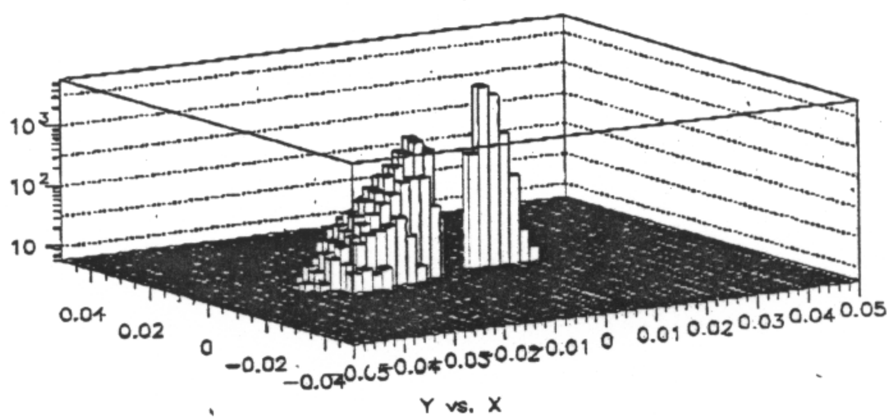
DI - JETS ANALYSIS

Used $\sim$ 1/3 of E791 data

Basic cuts:

- $\Sigma p_z > 450$ GeV/c (in charged tracks)
- Jet Finder - JADE Algorithm.
- Select DI - JETS Events only.

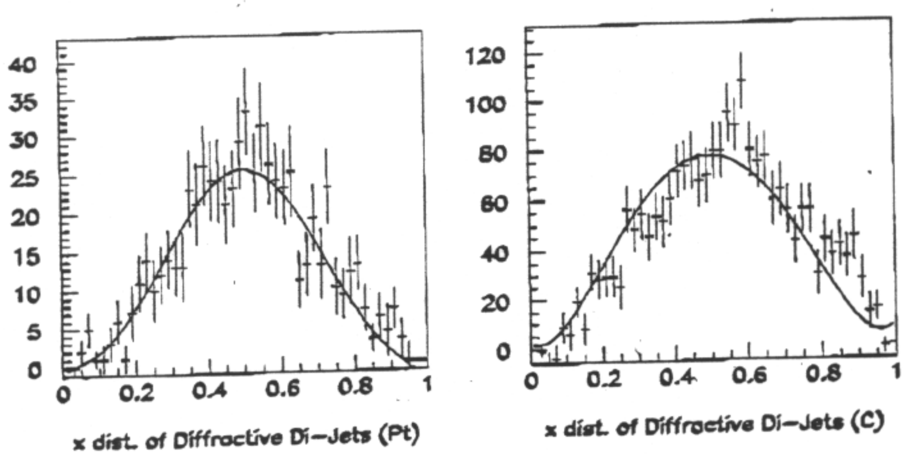




E791 DATA - THE $q\bar{q}$ MOMENTUM WAVE FUNCTION

AS MEASURED BY THE DI-JETS

- Use the diffractive di-jets to extract the momentum x distribution.
- Fit to a combination of the two wave function simulations. The asymptotic Brodsky Lepage function is dominant.



PION MOMENTUM WAVE FUNCTION

Two Functions were proposed for the $q\bar{q}$ configuration:

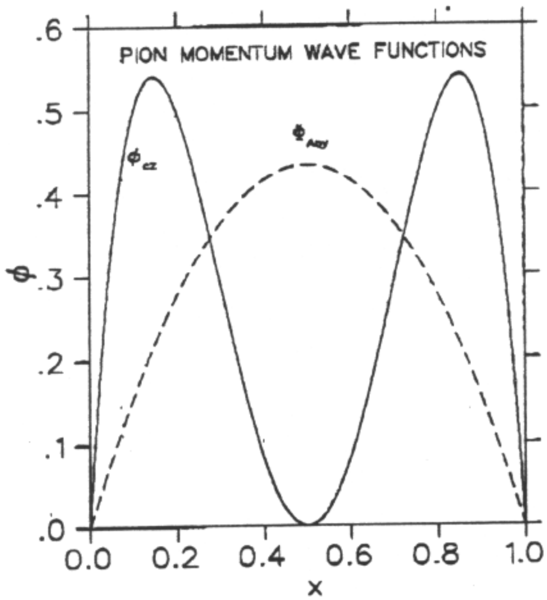
1. The Asymptotic Function (Brodsky and Lepage)

$$\phi_{as}(x) = \sqrt{3}x(1-x) \tag{1}$$

2. The Chernyak-Zhitnitsky Function

$$\phi_{cz}(x) = 5\sqrt{3}x(1-x)(1-2x)^2 \tag{2}$$

x is the fraction of the longitudinal momentum of the pion carried by a quark in the infinite momentum frame.



In the diffractive dissociation of the $|q\bar{q}>$ configuration into DJ, x can be measured by the momentum ratio of the two jets:

$$x_{measured} = \frac{p_{jet1}}{p_{jet1} + p_{jet2}} \tag{3}$$

SUMMARY:

The $q\bar{q}$ Spatial Wave Function:

Studied via the A-dependence of diffractive dissociation of pions to two jets. The result:

$$\int \left(\frac{d\sigma}{dt}\right) dt \propto A^{\alpha} \qquad \alpha = \overset{1.50}{\cancel{1.20}} \pm 0.05$$

Is in agreement with Color Transparency expectations.

The $q\bar{q}$ Momentum Wave Function:

Studied by the longitudinal momentum of diffractive dissociation of pions to two jets.

The diffractive region is dominated by the asymptotic function as suggested by Brodsky and Lepage:

$$\phi_{as}(x) = \sqrt{3}x(1-x).$$

E791 Expt:

* Sensitive to small size component in projectile pion

* Nucleus left intact

* Coherent, Every nucleon contributes

* High enough energy $t_{min} \sim 0$

* Component does not expand during transit thru nucleus

* <u>Color</u> <u>transparency</u>

* $\phi_\pi(x) \propto x\,(1-x)$

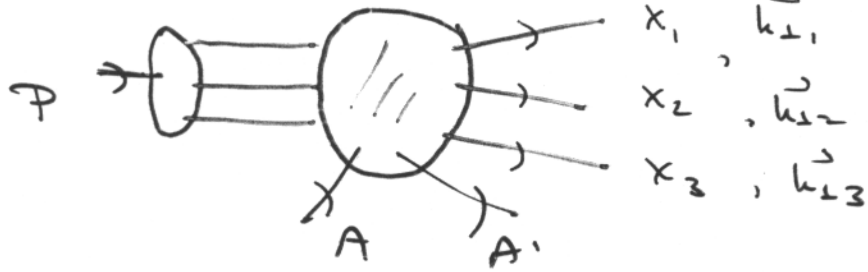
  asymptotic soln

  to evol. eqn

$$\int_0^1 dx\, \phi_\pi(x) = f_\pi \frac{2}{\sqrt{3}}$$

Nuclear Diffraction

Test at HERA-II
FNAL, RHIC ?

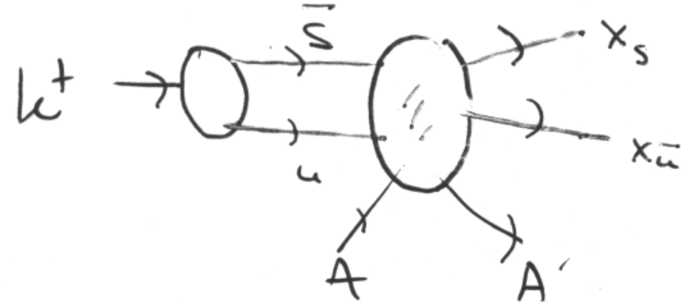


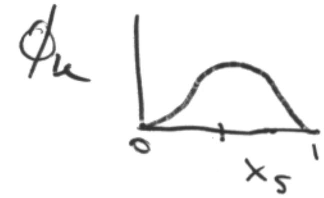
$\sum x_i \cong 1$

$\sum \vec{k}_{\perp i} \cong \vec{0}_\perp$

measure nucleon $\psi_{3q}(x_i, \vec{k}_{\perp i})$

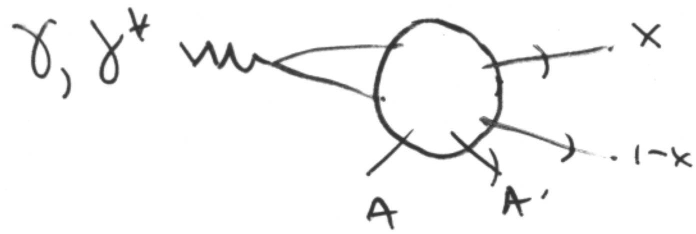
Factorization





$\langle x_s \rangle > 1/2$?

A. Martin et al



$\sigma_T : \; x^2 + (1-x)^2$

$\sigma_L : \; x(1-x)$

measure $\psi_{q\bar{q}/\gamma^*}(x, k_\perp)$ charm component

$eA \to e' A' \, J \, J$ rapidity gap

Hoyer, Magnea, SJB

Shape of $\phi_\pi(x_i, Q)$

$\left\{ \begin{array}{l} F_{\gamma^*\gamma \to \pi^0}(Q^2) \\ \\ \text{E791} \quad \text{Diffractive Di-Jet} \end{array} \right.$

$$\pi A \to J_1 J_2 A$$

* both suggest $\phi_\pi(x, Q) \cong \phi_{Asym}(x)$

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

why?

Highly relativistic quarks in pion

Maybe: $\phi_\Delta(x_i) = C_1 x_1 x_2 x_3$

$\phi_p(x_i)$: asymmetric

due to SU(6) Flavor-spin

$\Rightarrow$ * $F_{1p}(Q^2) \sim \frac{1}{Q^4}$; $F_{p \to \Delta}(Q^2) \sim \frac{1}{Q^6}$

Stoler, Carlson