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Measurement of the photon Light-Cone wave function by diffractive dissociation

Outline

Wave Functions, Structure Functions and Form Factors

Comments on Measurement of the Pion Valence LCWF

Measurement of the EM component of the Photon LCWF

Measurement of the hadronic component of the Photon LCWF

LCWF of the proton

Summary

Light-Cone Wave Functions:

Solutions of LC Hamiltonian: $H_{LC}^{QCD}|\psi_h\rangle = M_h^2|\psi_h\rangle$

$$H_{LC}^{QCD} = P^+P^- - P_\perp^2$$

Fock States Expansion for the Pion:

$$\begin{aligned} |\psi_{\pi^-}> &= \sum_n < n|\pi^- > |n> \\ &= \psi^{(\Lambda)}_{d\bar{u}/\pi}(u_i, \vec{k}_{\perp i}, \lambda_i)|\bar{u}d> \\ &\quad + \psi^{(\Lambda)}_{d\bar{u}g/\pi}(u_i, \vec{k}_{\perp i}, \lambda_i)|\bar{u}dg> + \cdots \end{aligned}$$

$$u_i = \frac{k_i^+}{p^+} = \frac{k_i^0 + k_i^z}{p^0 + p^z}, \qquad \sum_{i=1}^{n} u_i = 1, \qquad \sum_{i=1}^{n} \vec{k}_{\perp i} = \vec{0}_\perp.$$

$k_\perp$ **is the quark (antiquark) transverse momentum.**

ANY parton with fractional momentum x:

$$G_{a/h}(x,Q) = \sum_n \int d[\mu_n] \left|\Psi^{(Q)}_{n/h}(u_i, \vec{k}_{\perp i}, \lambda_i)\right|^2 \sum_i \delta(x - u_i)$$

Parton Distribution Functions Derived from *inclusive* DIS cross sections.

VALENCE QUARK with fractional momentum u:

$$\phi_{q\bar{q}}(u) \;\sim\; \int_0^{Q^2} \psi_{q\bar{q}}(u, k_\perp) dk_\perp^2 \qquad Q^2 \;=\; \frac{k_\perp^2}{u(1-u)}$$

For not too small Q^2:

$$\psi(u, k_\perp) \;\sim \frac{\phi(u)}{k_\perp^2}$$

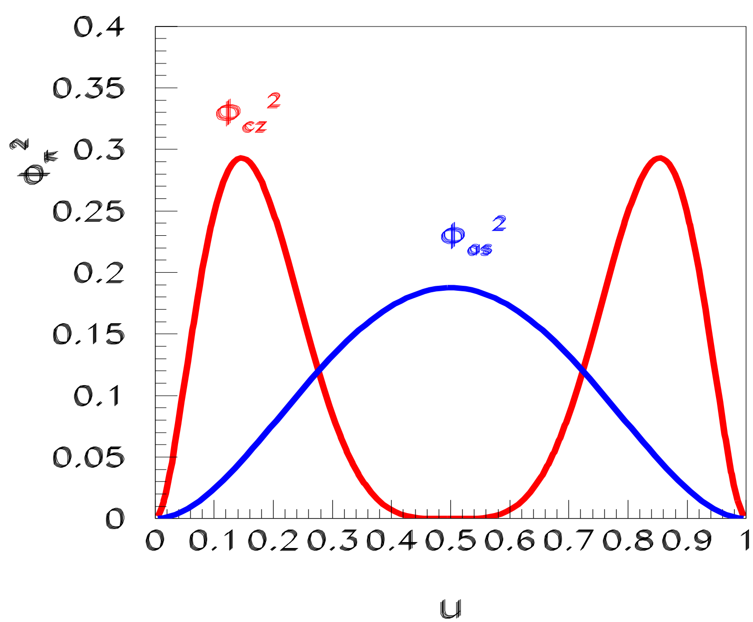
Distribution Amplitude $\phi(u)$, an *exclusive* quantity.

PION DISTRIBUTION AMPLITUTES

$$\phi_\pi(u,\mu^2) = u(1-u)\sum_{n\geq 0} a_n C_n^{3/2}(2u-1)(\ln\frac{\mu^2}{\Lambda^2})^{-\gamma_n/2\beta_2}$$

1. The Asymptotic Function: $a_2 = 0, a_4 = 0$
   pQCD; for $Q^2 \to \infty$: $\phi_{Asy}(u) = \sqrt{3} f_\pi u(1-u)$

2. The Chernyak-Zhitnitsky Function: $a_2 = 0.4, a_4 = 0$
   QCD sum rules; for low Q^2: $\phi_{cz}(u) = 5\sqrt{3} f_\pi u(1-u)(1-2u)^2$

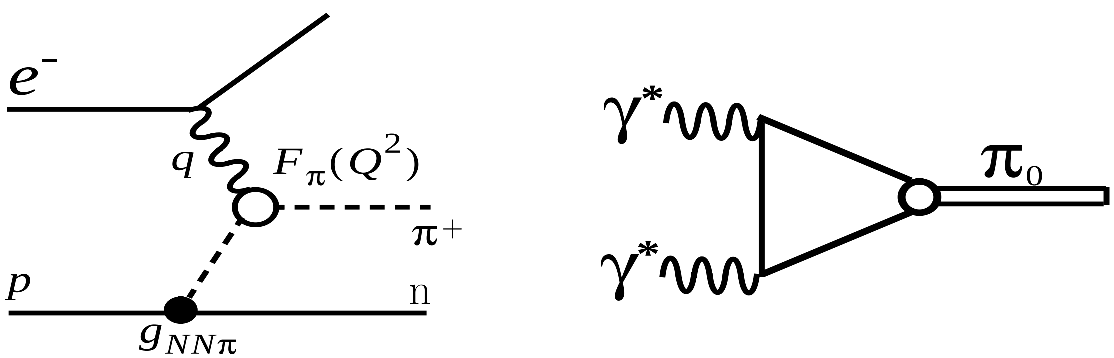


(1) **G.P. Lepage, S.J. Brodsky, Phys. Lett.B87, 359 (1979)**
A.V. Efremov, A.V. Radyushkin, Theor. Math. Phys. 42, 97 (1980).
(2) **V.L. Chernyak and A.R. Zhitnitski, Phys. Rep. 112,173 (1984).**

THE PION FORM FACTOR and WAVE FUNCTION

Space-Like Form Factor Measurements:

- $\pi \; e \;\; \longrightarrow \pi \;\; e$:   Very low Q^2
- $p(e, e'\pi^+)n$ $e^+ \; + \; e^- \longrightarrow \pi^0$

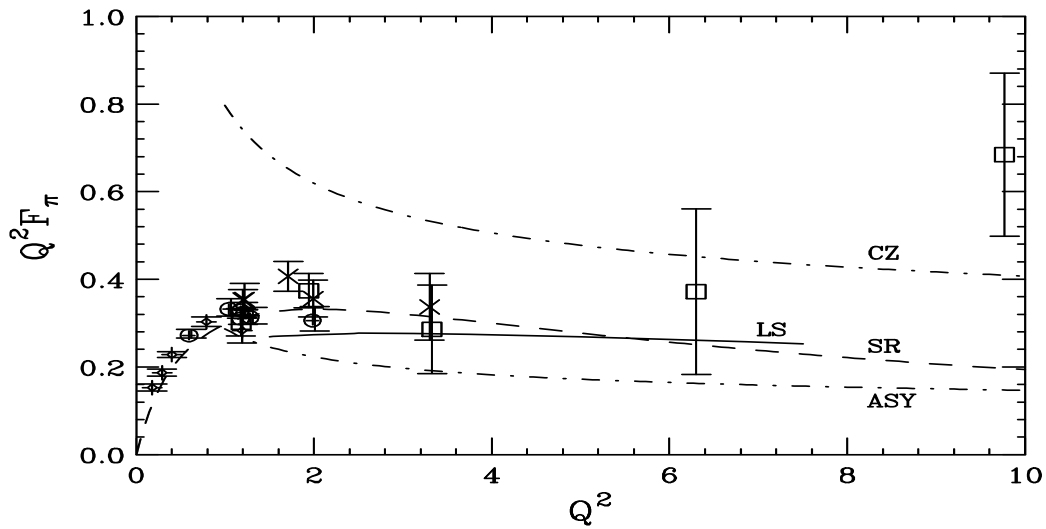


(a)   (b)

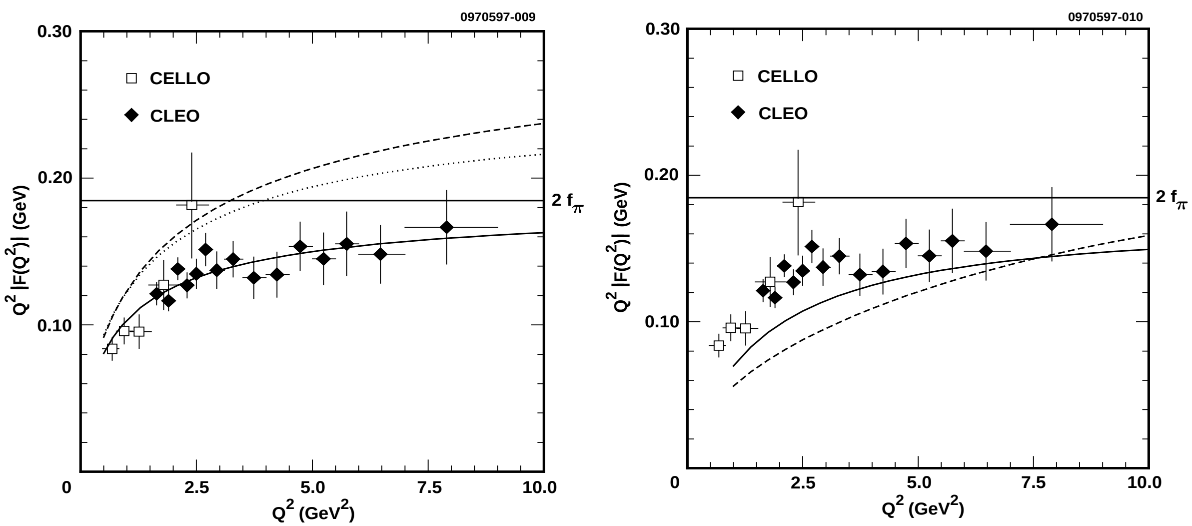
$$\sigma_L \sim -\frac{t g^2_{\pi NN}(t)}{(t - m^2_\pi)^2} F^2_\pi(Q^2)$$

$$F_\pi(Q^2) = \int_0^1 dx \; dy \; \boxed{\phi_\pi(y, \mu^2)} \; T(y, x, Q^2, \mu^2) \; \boxed{\phi_\pi(x, \mu^2)}, \qquad x, \; y \;\; = \;\; \frac{p_{quark}}{p_\pi}$$

Space-Like π^+ Form Factors (G. Sterman, P. Stoler, A.R.N.P.S. 43, 193 (1997))



π^0 Transition Form Factor CLEO Col. Phys. Rev. D57, 33 (1998)



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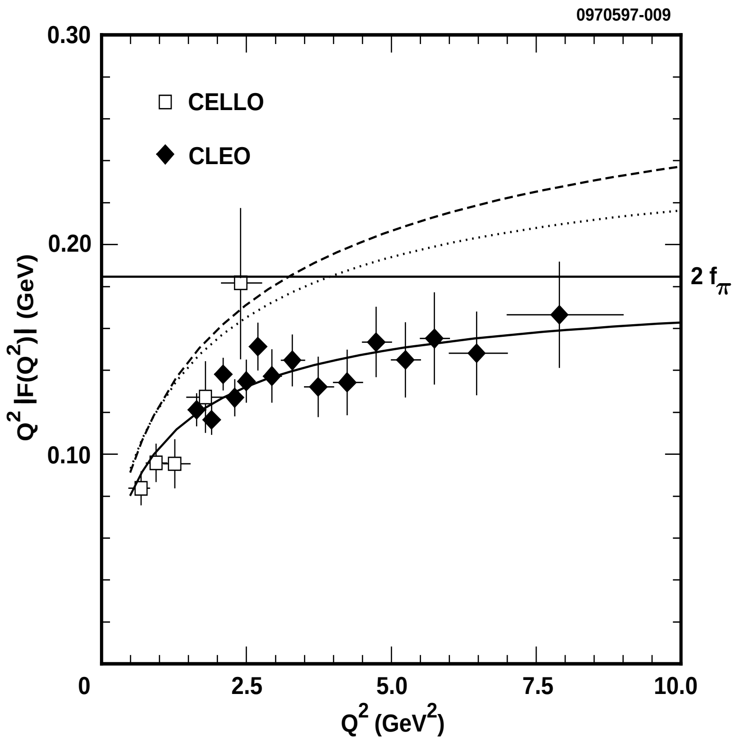
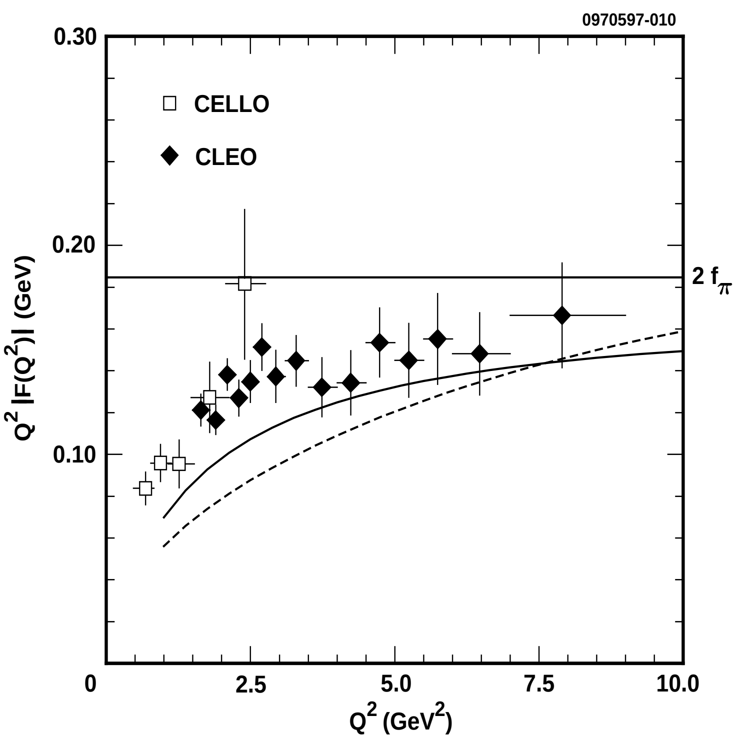
π^0 Transition Form Factor

CLEO Col. Phys. Rev. **D57**, 33 (1998)

Asymptotic Wave Function (solid lines), CZ Wave Function (dashed lines)

R. Jakob *et al.* J. Phys. G22, 45 (1996) **F.-G. Cao *et al.* Phys. Rev D53, 6582 (1996)**





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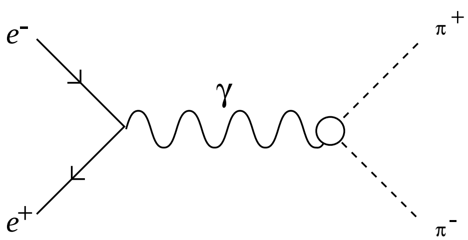
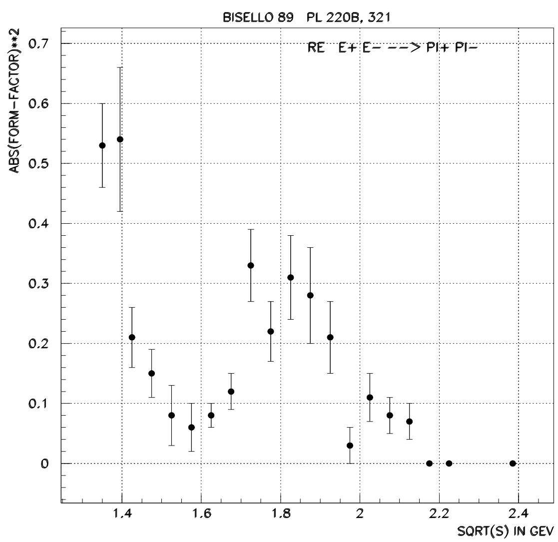
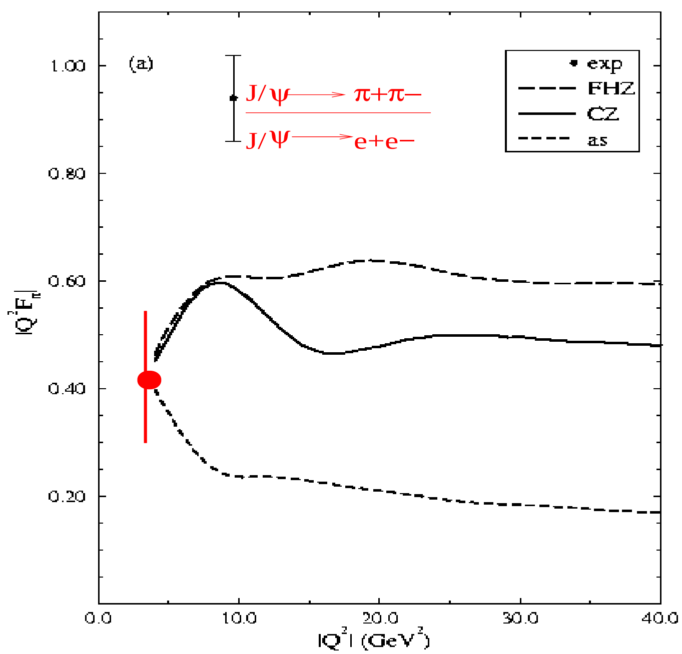
Time-Like Form Factor ($q^2 \ > \ 0$)

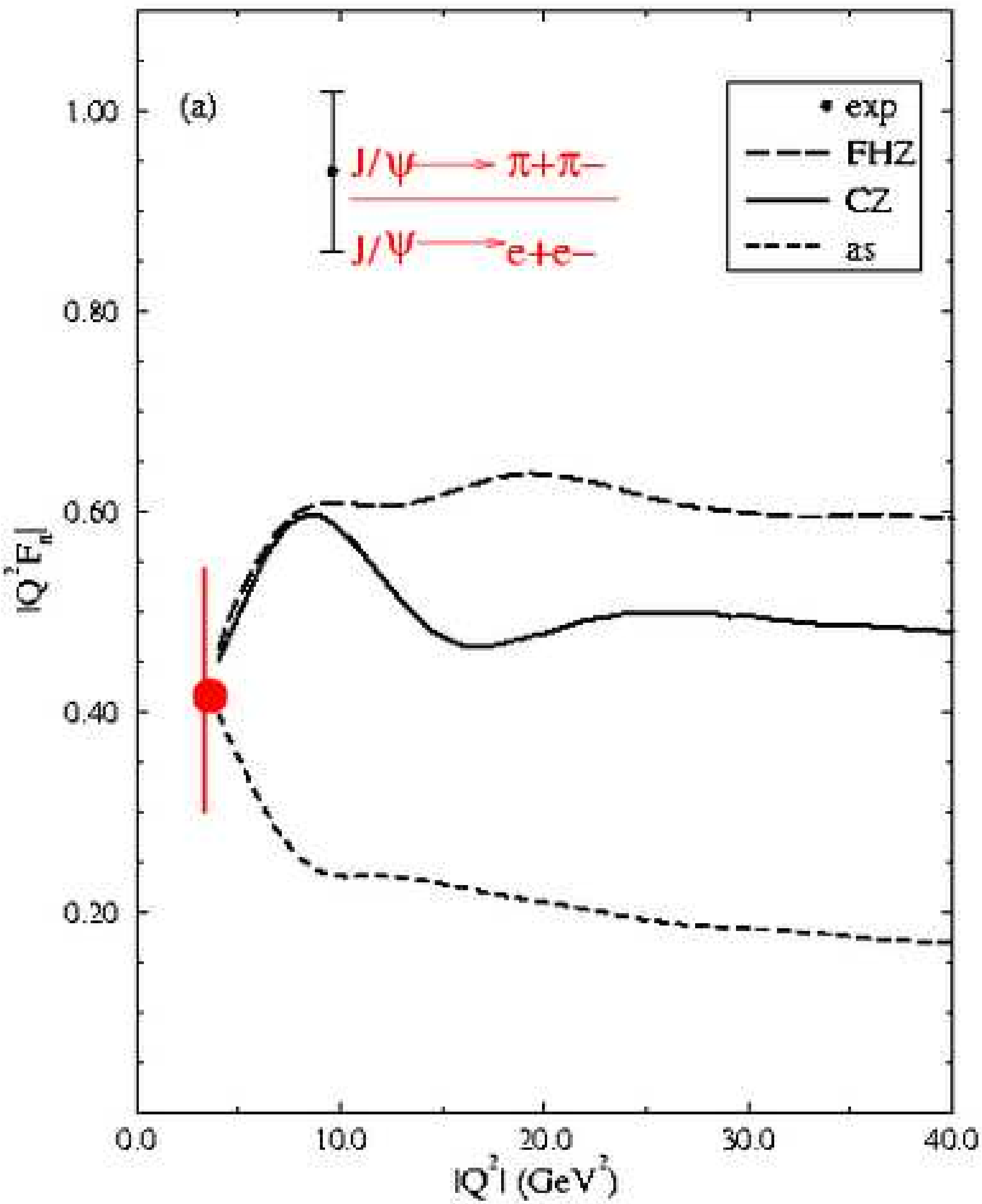


$$\sigma = \sigma(e^+e^- \to q\bar{q})|F_\pi(s)|^2 = \frac{\alpha^2\pi}{3}\frac{(s-4m_\pi^2)^{3/2}}{s^{5/2}}|F_\pi(s)|^2.$$

DM2 Coll. Phys. Lett. **B220**, 321 (1989) Gousset and Pire, Phys. Rev. **D51**, 15 (1995)







(a)
J/ψ⟶π+π−
J/ψ⟶e+e−
exp
FHZ
CZ
as
1.00
0.80
0.60
0.40
0.20
0.0
10.0
20.0
30.0
40.0
|Q²F_π|
|Q²| (GeV²)

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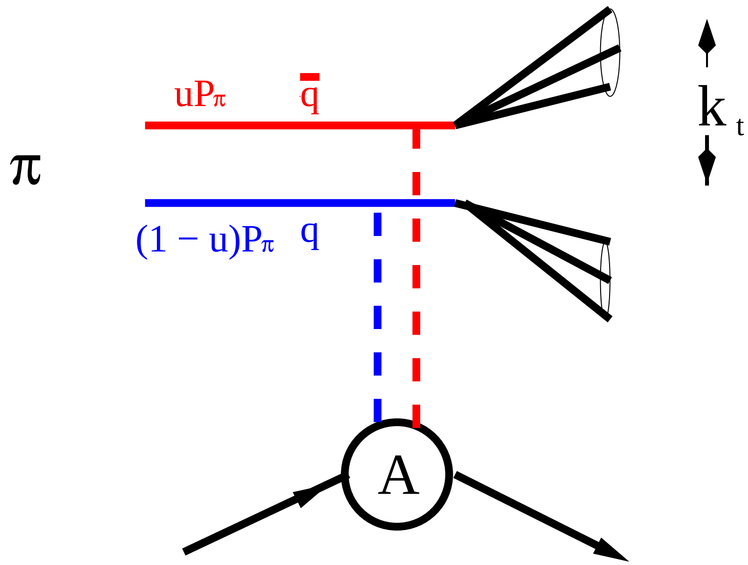
Differential Measurement of the Pion Wave Function



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

$$u_{measured} = \frac{p_{jet1}}{p_{jet1} + p_{jet2}}, \qquad Q^2_{DJ} = \frac{k_t^2}{u(1-u)}$$

L. Frankfurt, G.A. Miller and M. Strikman,
P.L. B304(1993)1

6. Cross-section Estimate

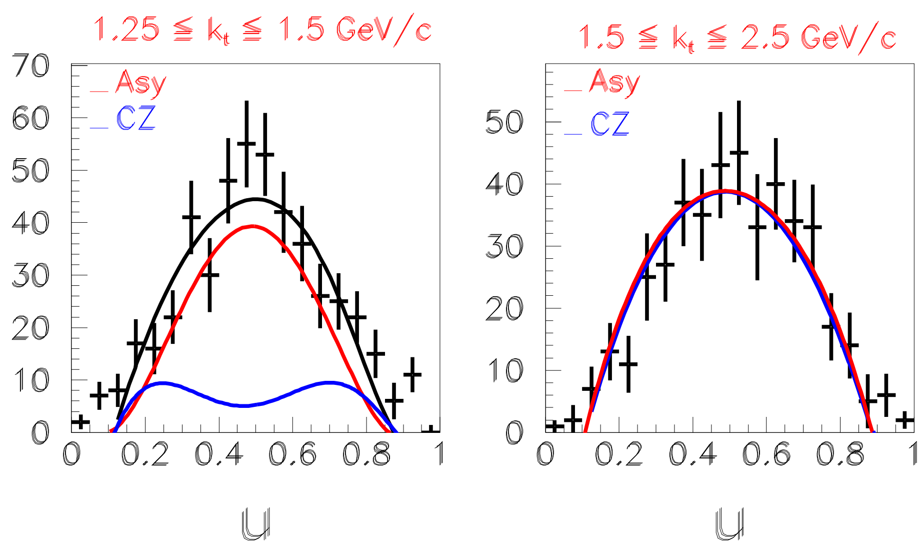
$$\frac{d^4\sigma_N}{dudM_J^2 \cdot d^2P_{N_t}} = 2.6 \text{ GeV}^{-6} \left(\frac{\text{GeV}}{\kappa_t}\right)^8 \phi^2(u), \tag{9}$$

“ with $g = 2$ and $L = 1GeV$. For κ_t = 2 GeV and at the maxima of $\phi(u)$ we find $\frac{d^3\sigma_N}{dxdM_T^2d^2P_{N_t}} = 1.8(3.0) \times 10^{-3}\,\text{GeV}^{-6}$ where the larger (smaller) value is obtained using ϕ_{cz} (ϕ_{as}) ”.

THE $q\bar{q}$ MOMENTUM WAVE FUNCTION

MEASURED BY DI-JETS

Fermilab E791 Collaboration, PRL 86, 4768 (2001)



$\underline{1.5\mathrm{GeV/c} \ \leq \ \mathrm{k_t} \ \leq \ 2.5\mathrm{GeV/c}; \ \ Q^2 \sim 16 \ (\mathrm{GeV/c})^2 :}$ $\quad \phi^2 \ > \ 0.9\phi^2_{Asy}$

$\underline{1.25\mathrm{GeV/c} \ \leq \ \mathrm{k_t} \ \leq \ 1.5\mathrm{GeV/c}; \ \ Q^2 \sim 8 \ (\mathrm{GeV/c})^2 :}$

ϕ^2 contains contributions from CZ or other non-perturbative wave functions

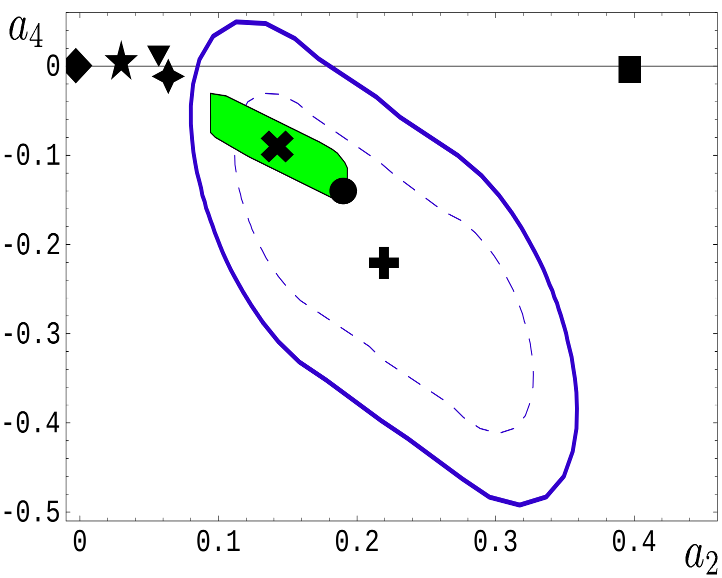
hep-ph/0303039

CLEO and E791 data: A smoking gun for the pion distribution amplitude?

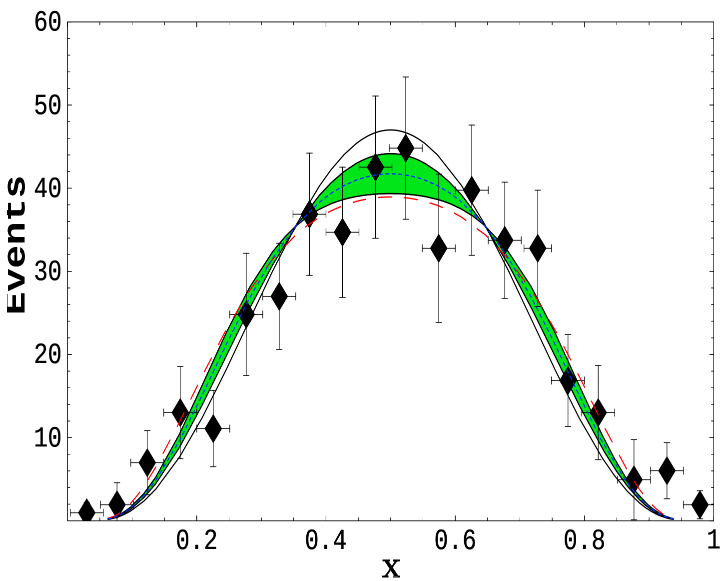
Alexander P. Bakulev, S. V. Mikhailov and N. G. Stefanis

$$\varphi_\pi^{BMS}(u) = \varphi_\pi^{as}(u)[1 + a_2^{opt} \cdot C_2^{3/2}(2u-1) + a_4^{opt} \cdot C_4^{3/2}(2u-1)]\,,$$

CLEO



E791 high k_t



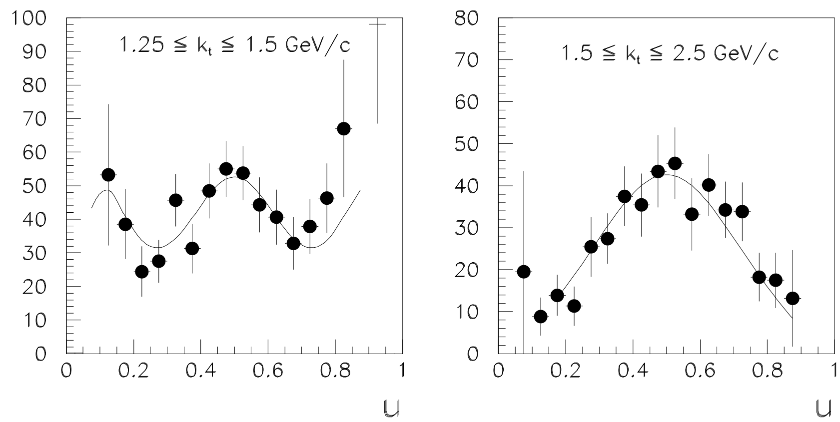
Fit to Gegenbauer Polynomials

Generate Acceptance-Corrected Momentum distributions

Assume $\frac{d\sigma}{du} \propto \phi_\pi^2(u, Q^2)$ **in both** $k_\perp$ **regions**

Fit distributions to:

$$\frac{d\sigma}{du} \propto \phi_\pi^2(u, Q^2) = 36u^2(1-u)^2 \left(1.0 + a_2 C_2^{3/2}(2u-1) + a_4 C_4^{3/2}(2u-1)\right)^2$$



For low k_t : $a_2 = 0.30 \pm 0.05, \quad a_4 = (0.5 \pm 0.1) \cdot 10^{-2}$

For high k_t : $a_2 = a_4 = 0 \rightarrow$ **Asymptotic**

THE k_t DEPENDENCE OF DI-JETS YIELD

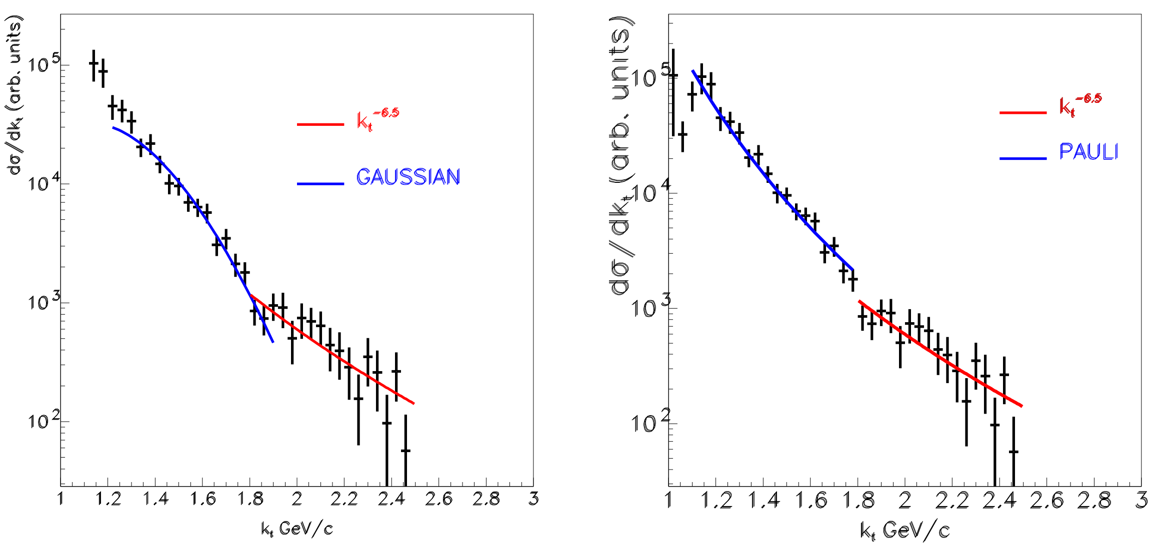
$$\frac{d\sigma}{dk_t^2} \propto \left|\alpha_s(k_t^2)G(x,k_t^2)\right|^2 \left|\frac{\partial^2}{\partial k_t^2}\psi(u,k_t)\right|^2$$

With $\psi \sim \frac{\phi}{k_t^2}$**, weak** $\phi(k_t^2)$ **and** $\alpha_s(k_t^2)$ **dependences and** $G(x,k_t^2) \sim k_t^{1/2}$: $\frac{d\sigma}{dk_t} \sim k_t^{-6}$

For low k_t**:**

Gaussian: $\psi \sim e^{-\beta k_t^2}$ **(Jakob and Kroll)**

Coulomb: $\psi(p) = \left(\frac{1}{1+p^2/p_a^2}\right)^2$ **(Pauli)**



Is $\sigma \propto \phi^2$??

hep-ph/0103275

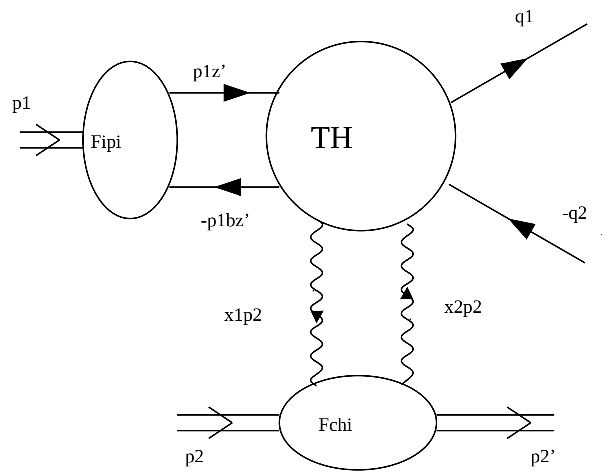
QCD factorization for the pion diffractive dissociation to two jets

V.M. Braun[1], D.Yu. Ivanov[1,2] A. Schäfer[1] and L. Szymanowski[1,3]

hep-ph/0103295

Has the E791 experiment measured the pion wave function profile ?

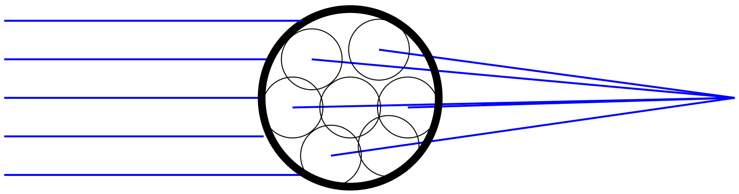
Victor Chernyak



When measured in a heavy nucleus $\underline{\sigma \propto \phi^2}$ (Brodsky, Frankfurt, Nikolaev, Braun...)

EXPECTED A-DEPENDENCE

FOR COLOR TRANSPARENCY



- **Fully coherent interactions between pion and nucleons.**

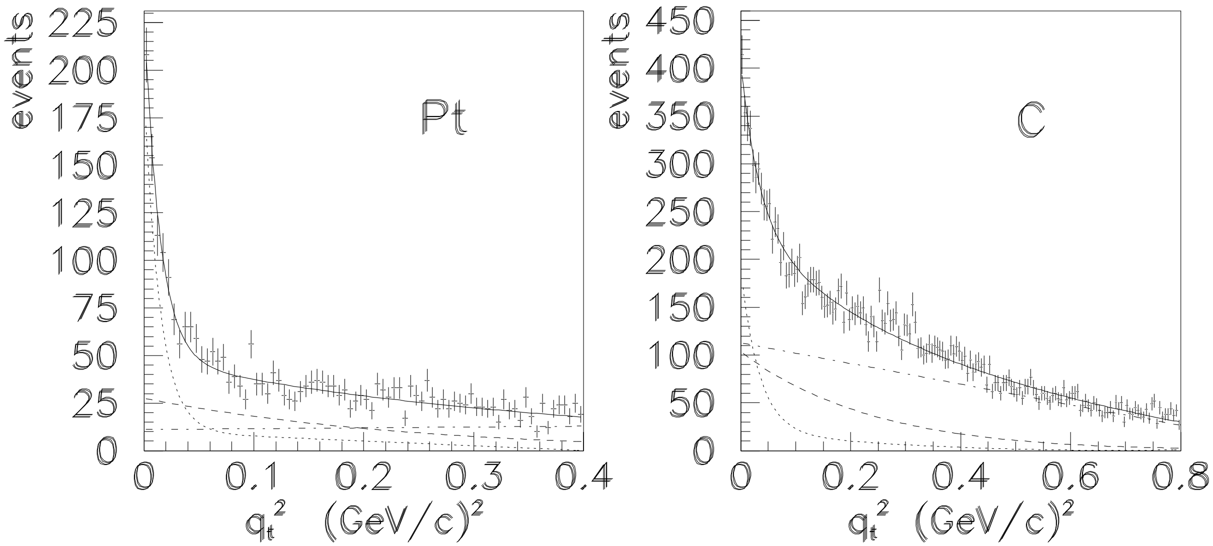
- **Emerging Di-Jets do not interact with nucleus.**

$$\mathcal{M}(\mathcal{A}) = \mathcal{A} \cdot \mathcal{M}(\mathcal{N})$$

$$\frac{d\sigma}{dq_t^2} \propto A^2 \quad q_t^2 \sim 0$$

$$\sigma \propto A^{4/3}$$

E791 Collaboration, E. Aitala *et al.*, Phys. Rev. Lett. 86, 4773 (2001)



A-Dependence results: $\sigma \propto A^{\alpha}$

k_t range (GeV/c)	α	α (CT)
$1.25 < k_t < 1.5$	1.64 +0.06 -0.12	1.25
$1.5 < k_t < 2.0$	1.52 ± 0.12	1.45
$2.0 < k_t < 2.5$	1.55 ± 0.16	1.60

α (Incoh.) $= 0.70 \pm 0.1$

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Measurements of the photon light-cone wave function

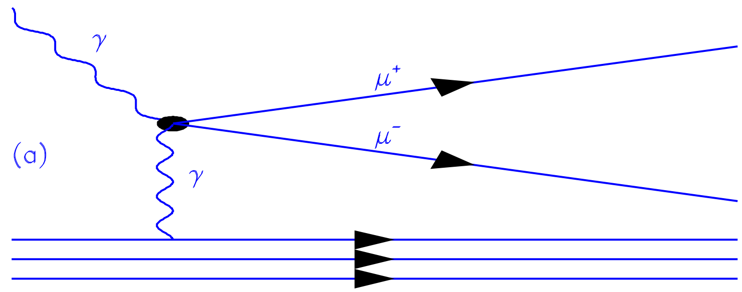
Fock state decomposition:

$$\psi_\gamma \;=\; a|\gamma_p\rangle + b|l^+l^-\rangle + c|l^+l^-\gamma\rangle + (other\ e.m.) + d|q\bar{q}\rangle + e|q\bar{q}g\rangle$$
$$+\ (other\ had.)\ + ...$$

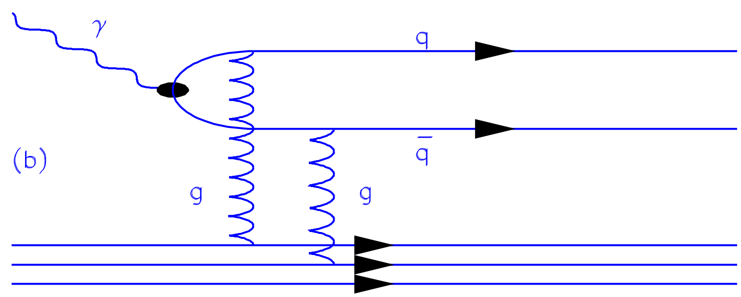
Electromagnetic and Hadronic components

Real and Virtual Photons

Transverse and Longitudinal polarizations



γ
μ+
μ-
(a)
γ



γ
q
(b)
q̄
g
g

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The electromagnetic $|l^+l^-\rangle$ component of the photon

The wave function of the first component of a photon with virtuality Q^2 is[1]:

$$\psi^{\lambda}_{\lambda_1\lambda_2}(k_\perp,u) = \; - \; ee_l \; \frac{\bar{l}_{\lambda_1}(k)\lambda\cdot\epsilon^{\lambda} l_{\lambda_2}(q-k)}{\sqrt{u(1-u)}\left(Q^2+\frac{k_\perp^2+m^2}{u(1-u)}\right)}$$

The distribution amplitude (squared) for transversly polarized photons:

$$\Phi^2_{l\bar{l}/\gamma^*_T}(u,k_\perp) \sim \sum_{\mu=1}^{2}\frac{1}{4}Tr\psi^2_{\gamma^*} = \frac{m_l^2+k_\perp^2[u^2+(1-u)^2)]}{[k_\perp^2+a_l^2]^2}, \quad a_l^2 = m_l^2+Q^2u(1-u).$$

For longitudinally polarized photons:

$$\Phi^2_{l\bar{l}/\gamma^*_L} \sim \frac{Q^2[u^2(1-u)^2]}{[k_\perp^2+a^2]^2}$$

(1)S. J. Brodsky, L. Frankfurt, J. F. Gunion, A. H. Mueller and M. Strikman, Phys. Rev. D50, 3134 (1994)

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The hadronic $|q\bar{q}\rangle$ component of the photon

For $k_\perp^2 \gg \Lambda_{QCD}^2$ the wave function of the $|q\bar{q}\rangle$ component of a photon with virtuality Q^2 is the same as for the $|l^+l^-\rangle$ component.

The distribution for massive quarks and transversly polarized photons:

$$\Phi^2_{q\bar{q}/\gamma_T^*}(u, k_\perp) \sim \frac{m_q^2 + k_\perp^2[u^2 + (1-u)^2)]}{[k_\perp^2 + a_q^2]^2}$$

where:

$$a_q^2 = m_q^2 + Q^2 u(1-u).$$

For low $k_\perp^2$ other predictions:

1. **Instanton models** **Petrov *et al.*, Phys.Rev. D59, 11401 (1999)**

2. **Asymptotic distribution: $\Phi^2_{q\bar{q}/\gamma} \sim u^2(1-u)^2$** **Balitsky *et al.*, Nucl. Phy. B312, 509 (1989)**

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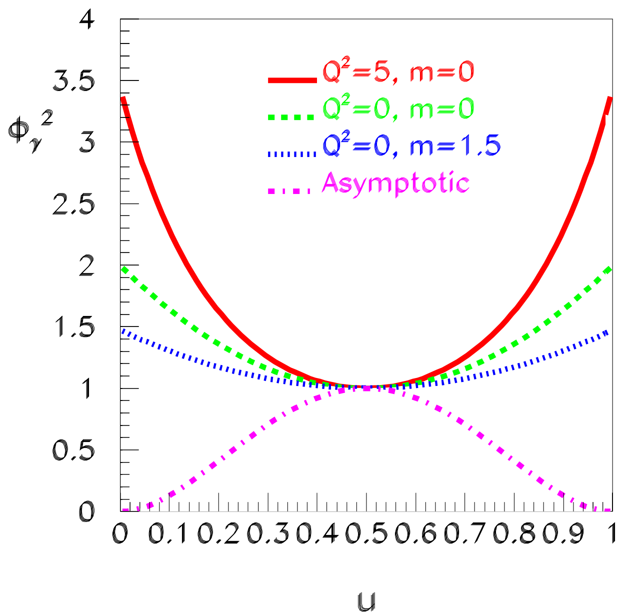
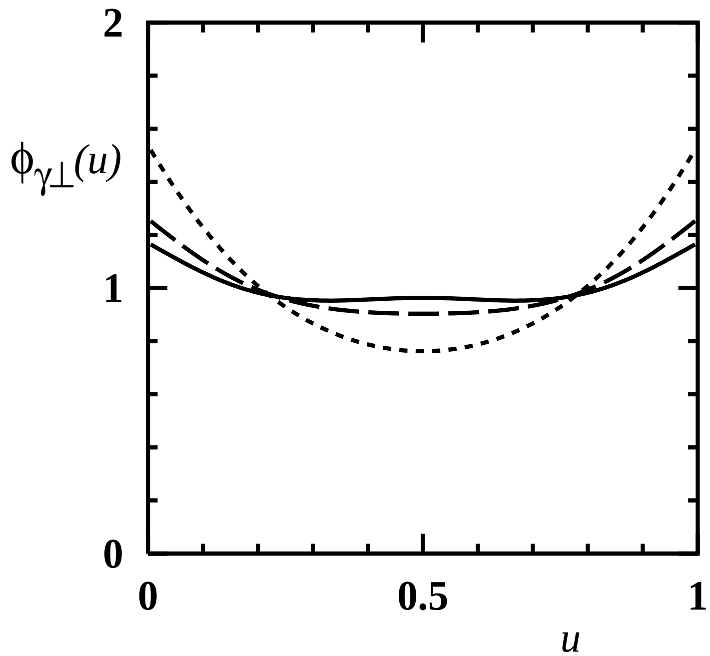
Φ Distributions of $|l^+l^-\rangle$, $|q\bar{q}\rangle$ components of the photon

Perturbative Wave functions

Instanton Wave Functions, real photons (solid line), virtual $Q^2 = 250$ MeV^2 (dashed line), $Q^2 = 500$ MeV^2 (dotted line).

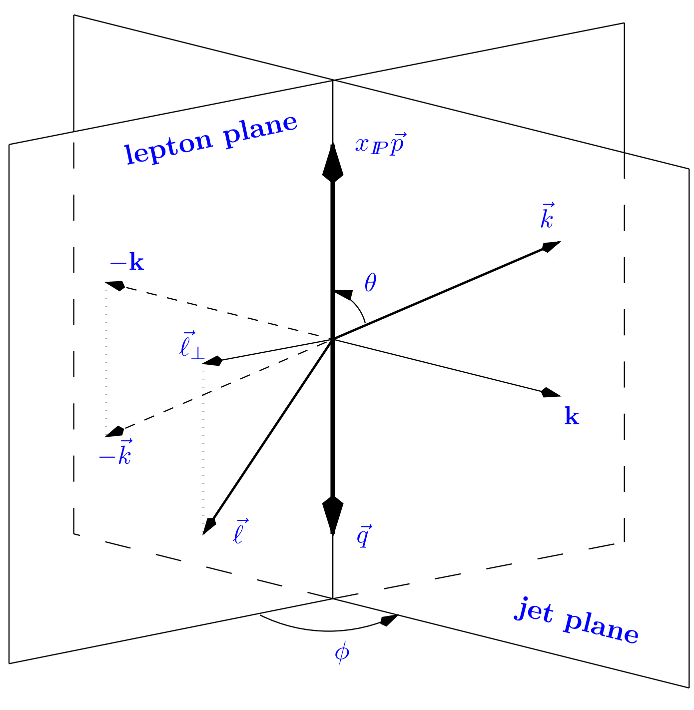


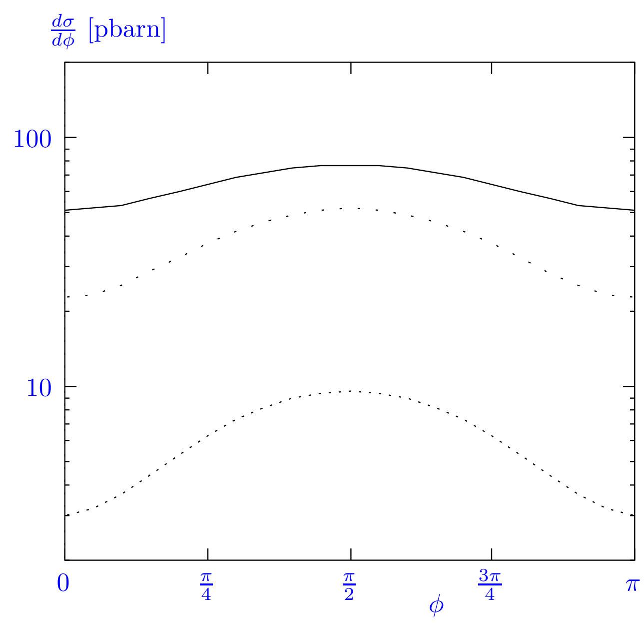


ϕ Distribution for $q\bar{q}$ Diffractive Dissociation to Dijets

J. Bartels *et al.*, Phys. Lett. **B386**, 389 (1996)

$$d\sigma_D^{e^-p} = \frac{\alpha_{em}}{yQ^2\pi}\left[\frac{1+(1-y)^2}{2}d\sigma_{D,T}^{\gamma^*p} - 2(1-y)\frac{\frac{k_t^2}{M^2}}{1-2\,\frac{k_t^2}{M^2}}cos2\phi\, d\sigma_{D,T}^{\gamma^*p}\right.$$
$$\left. + (1-y)d\sigma_{D,L}^{\gamma^*p} + (2-y)\sqrt{(1-y)}cos\phi d\sigma_{D,I}^{\gamma^*p}\right]$$

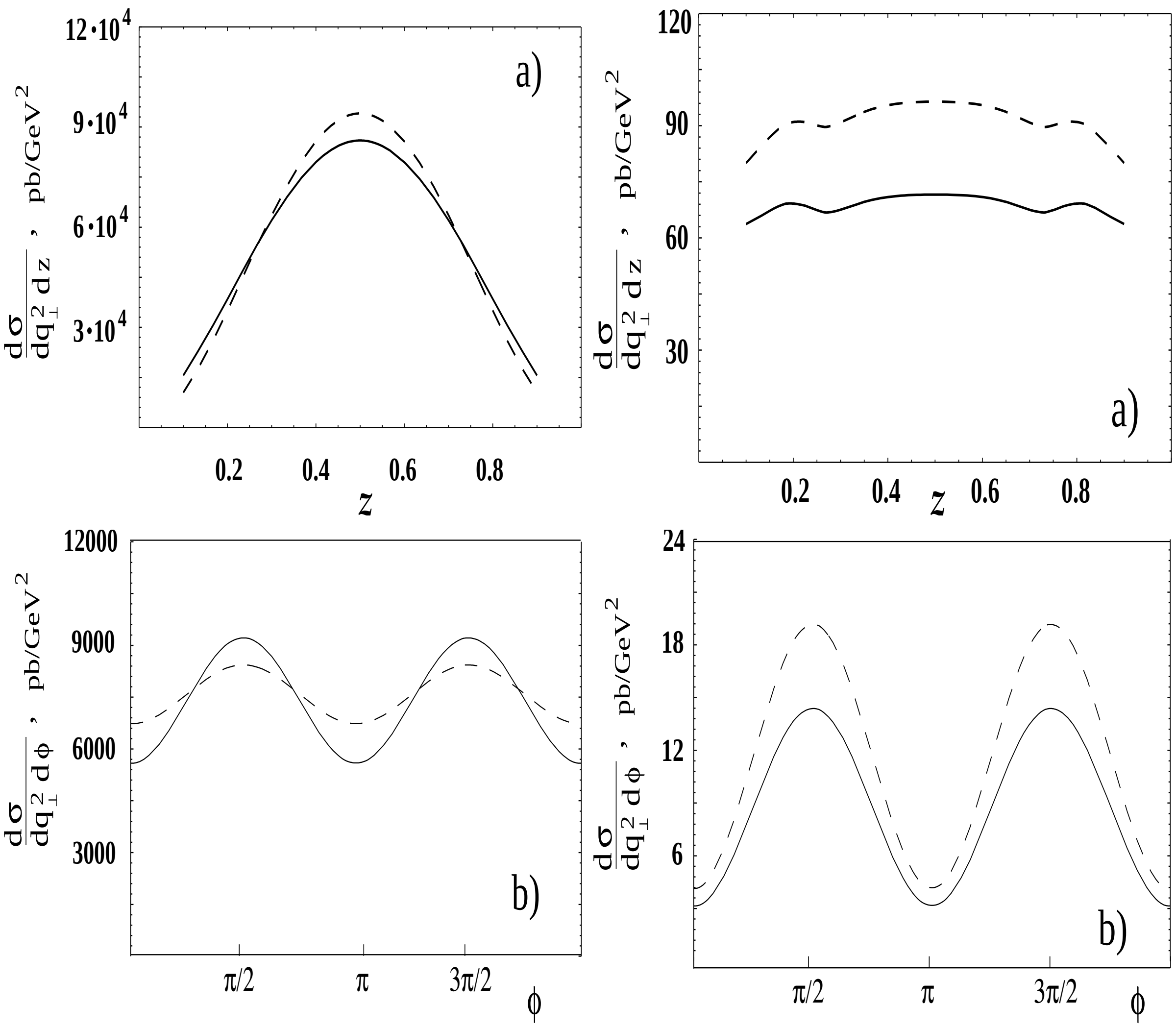




Photoproduction: V.M. Braun *et al.* PRL 89 (2002) 172001

$k_\perp = 2GeV/c$, chiral-odd $\qquad$ $k_\perp = 5GeV/c$, chiral-even

$\uparrow\uparrow, \quad L_z = 0$ $\qquad$ $\uparrow\downarrow, \quad L_z = 1$



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Measurements of the photon light-cone wave function ZEUS/HERA/DESY

Channels:

$\gamma \; p \rightarrow \mu^+\mu^- \; p$	**Janusz Szuba, UMM Cracow**	**Justyna Ukleja, Warsaw U.**
$\gamma^* \; p \rightarrow 2J \; p$	**Iuliana Cohen, TAU**	**Janusz Szuba, UMM Cracow**
$\gamma^* \; p \rightarrow \pi^+\pi^- \; p$	**Eyal Nevo, TAU**	**Justyna Ukleja, Warsaw U.**

Acknowledgements:

Halina Abramowicz

Vladimir Braun, Stan Brodsky, Leonid Frankfurt, Markus Diehl, Boris Kopeliovich ....

Electromagnetic component of LCWF:

Photoproduction of DiMuons (Bethe-Heitler)

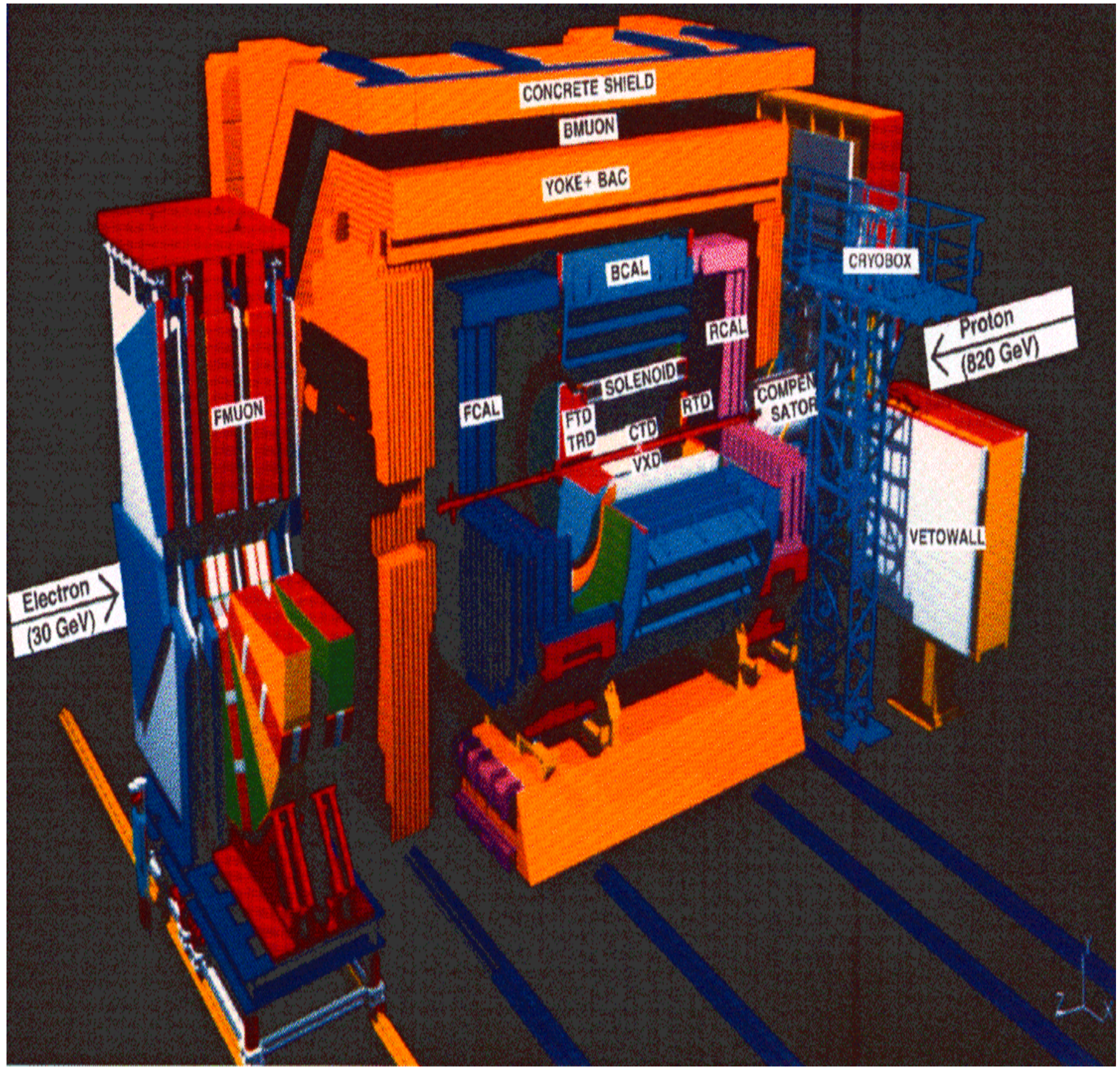
$$\frac{d\sigma_T}{dt\ du\ dk_t^2}\bigg|_{t=0} \propto Tr|\frac{\partial}{\partial k_\mu}\psi_\mu^T|^2$$

$$\frac{d\sigma_T}{dt\ du\ dk_t^2} \propto \frac{4m_l^2 k_t^2 + 2(k_t^4 + a^4)[u^2 + (1-u)^2]}{(a^2 + k_t^2)^4}$$

$a^2 = Q^2 u(1-u) + m_l^2$.

For real photons and using $m_l = 0 \to a = 0$**:**

$$\frac{d\sigma_T}{dt\ du\ dk_t^2} \propto \frac{2[u^2 + (1-u)^2]}{k_t^4} \sim \frac{\Phi^2}{k_t^2}.$$


CONCRETE SHIELD
BMUON
YOKE+ BAC
CRYOBOX
BCAL
RCAL
Proton
(820 GeV)
SOLENOID
FCAL
FTD
TRD
CTD
RTD
COMPEN
SATOR
VXD
FMUON
VETOWALL
Electron
(30 GeV)

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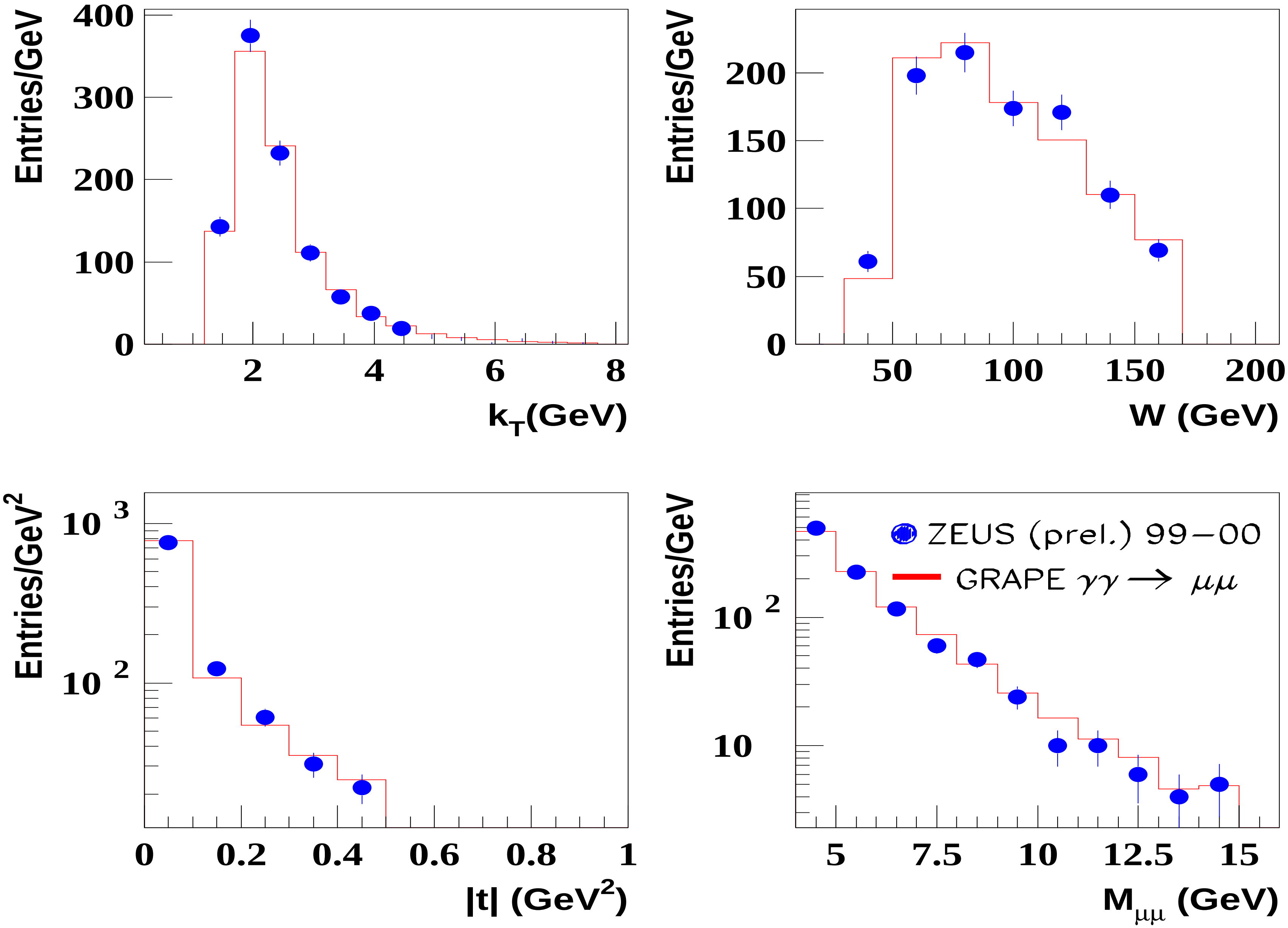
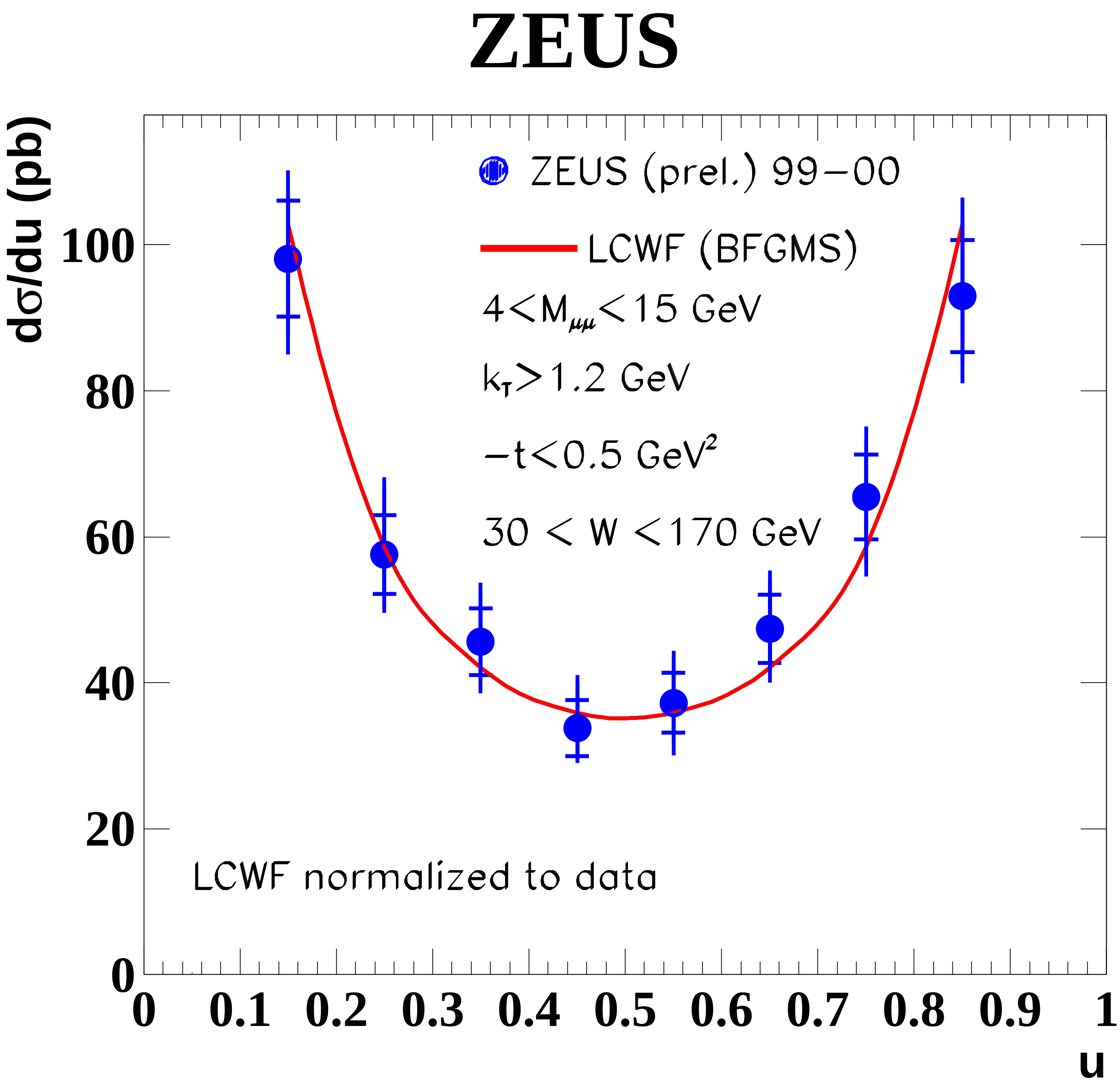
Event Selection for $\gamma\ p \rightarrow \mu^+\mu^-\ p$

- μ **Trigger**
- **Proton did not disintegrate**
- **Elasticity (only 2**μ **in event)**
- **Diffractive (small** t**)**
- $4 \leq M_{\mu^+\mu^-} \leq 15 GeV$ **(avoid resonances)**
- **Various cleaning cuts**

ZEUS



Entries/GeV
400
300
200
100
0
2
4
6
8
k_T(GeV)
Entries/GeV
200
150
100
50
0
50
100
150
200
W (GeV)
Entries/GeV^2
10^3
10^2
0
0.2
0.4
0.6
0.8
1
|t| (GeV^2)
Entries/GeV
10^2
10
5
7.5
10
12.5
15
$M_{\mu\mu}$ (GeV)
ZEUS (prel.) 99−00
GRAPE $\gamma\gamma \rightarrow \mu\mu$


ZEUS
ZEUS (prel.) 99−00
LCWF (BFGMS)
4<M$_{\mu\mu}$<15 GeV
k$_T$>1.2 GeV
−t<0.5 GeV^2
30 < W <170 GeV
LCWF normalized to data
dσ/du (pb)
u
0
20
40
60
80
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

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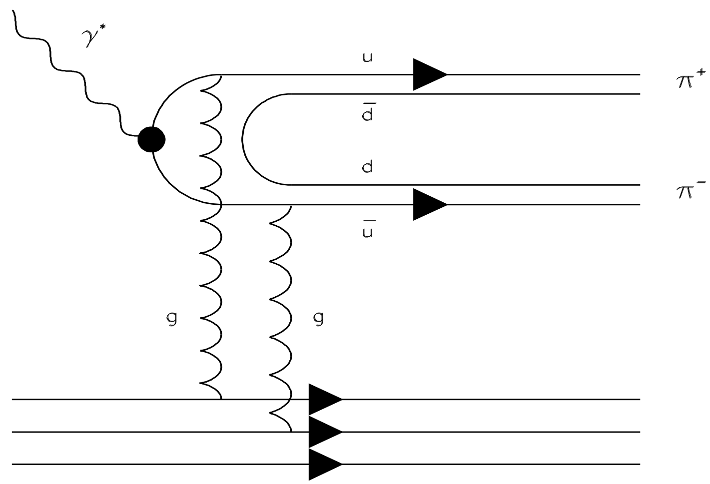
Hadronic component - special case: $\gamma^* \, p \longrightarrow \pi^+\pi^- \, p$



Relation to pion Time-Like form factor ?

$$\frac{\sigma(\gamma^* + p \longrightarrow 2\pi + p)}{\sigma(\gamma^* + p \longrightarrow X + p)} \propto |F_\pi|^2$$

Pion quantum numbers ? Longitudinal/Transverse ?

Pomeron - Odderon interference

The Odderon: 3g color singlet, Charge-parity C = -1

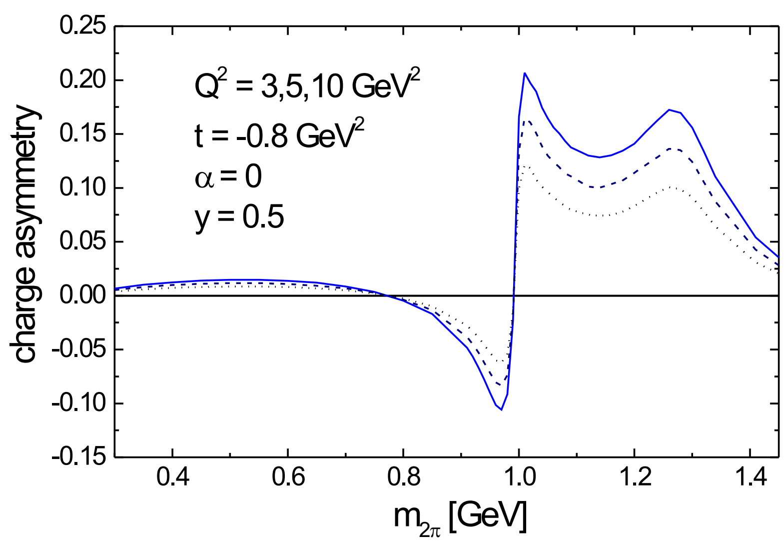
$C(\pi^+\pi^-) \;=\; (-)^\ell$: **produced by both Pomeron and Odderon.**

Pomeron-Odderon Interference:
Brodsky, Rathsman and Merino, Phys. Lett. B461, 114 (1999)

Results in charge asymmetry:

$$A = \frac{u(\pi^+) - u(\pi^-)}{u(\pi^+) + u(\pi^-)}$$

Hagler, Szymanowski and Teryaev Phys. Lett. B535, 117 (2002):



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Event Selection for $\gamma^* \, p \longrightarrow \pi^+\pi^- \, p$

- $E_{e'} \; > \; 10$ **GeV**
- **Proton did not disintegrate**
- **Pion identification by Neural Net**
- **Elasticity (only 2π in event)**
- **Various cleaning cuts**
- **Diffractive (small t)**
- $1.2 \leq M_{\pi^+\pi^-} \leq 5 GeV$
- $2 < Q^2 < 20 GeV^2$
- $40 \; < \; W \; < \; 120$ **GeV**

$$\beta = \frac{Q^2}{Q^2 + M_X^2}$$

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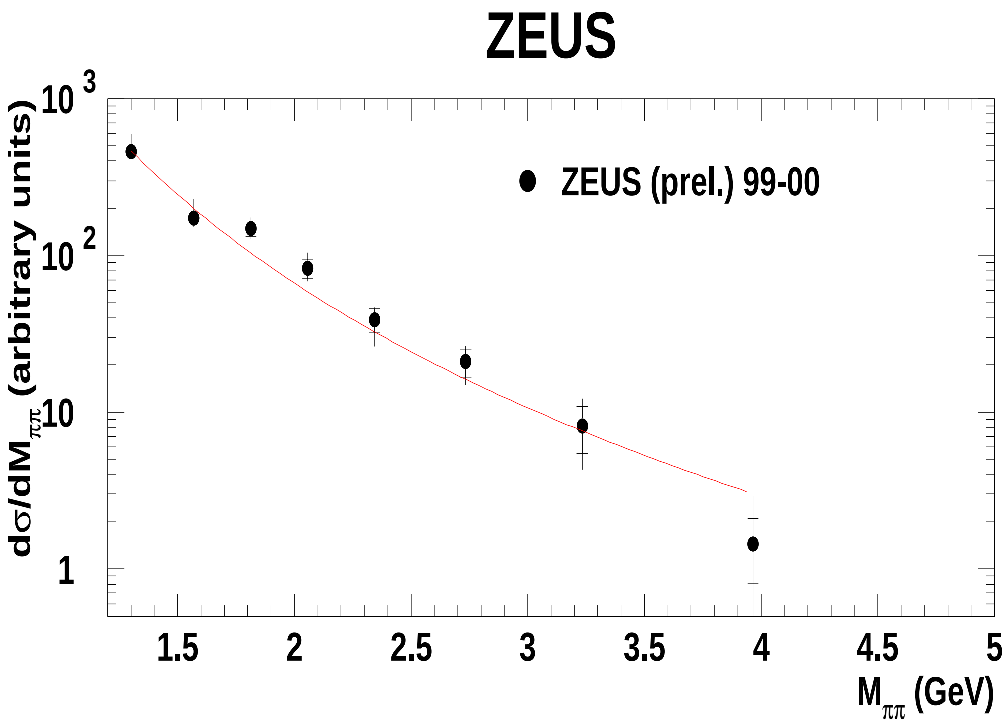
Mass Dependence



Fit : $M_{\pi\pi}^{-4.5}$

Future derivation of Time-Like $|F_\pi|^2$

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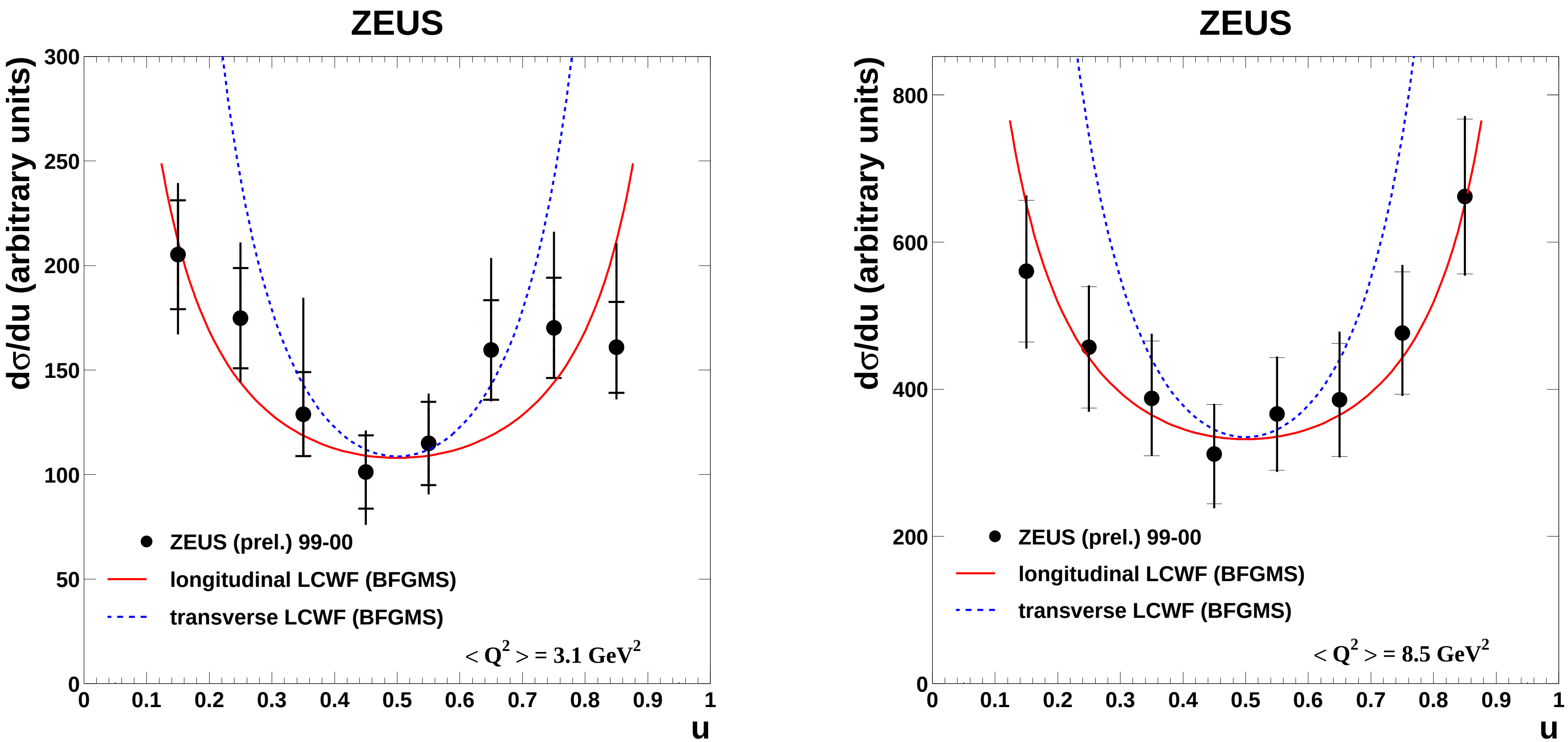
u Dependence



$$< \beta > \ = \ 0.52 \qquad\qquad < \beta > \ = \ 0.75$$

Longitudinal photon fluctuating to $q\bar{q}$.

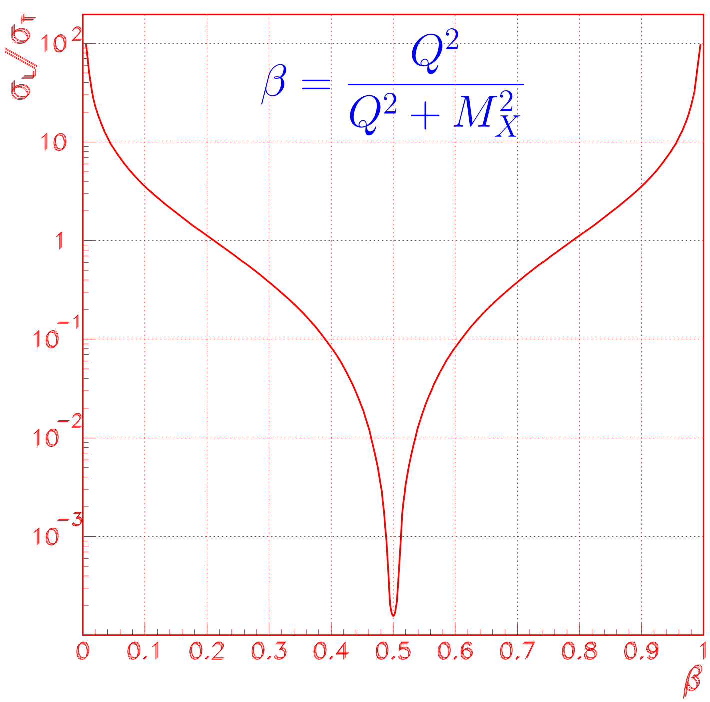
Cross section for diffractive dissociation to $q\bar{q}$:

$$\left.\frac{d\sigma}{dt\ du\ dk_t^2}\right|_{t=0} \propto |Tr\Delta\psi|^2. \quad For\ m_q = 0:$$

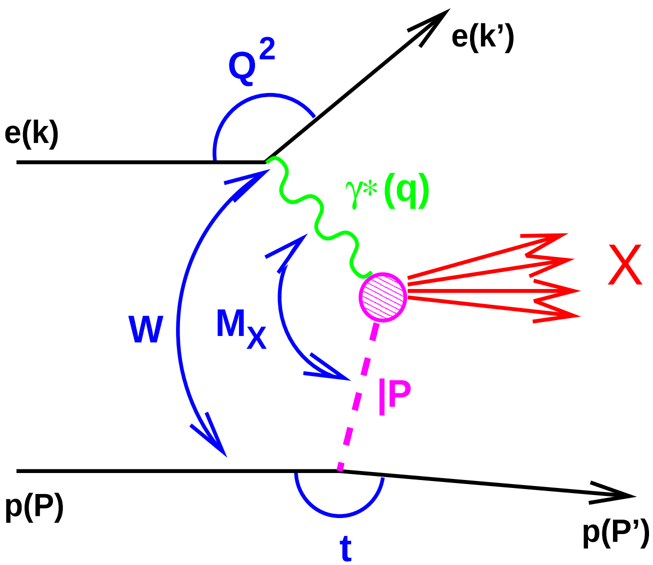
$$\frac{d\sigma_L}{dt\ du\ dM^2} = \frac{\pi\alpha_s^2}{9} e^2 Q^2 \sum e_q^2 (xg)^2 \cdot \frac{(Q^2-M^2)^2}{(Q^2+M^2)^6} \cdot \frac{1}{u(1-u)}$$

$$\frac{d\sigma_T}{dt\ du\ dM^2} = \frac{\pi\alpha_s^2}{18} e^2 \sum e_q^2 (xg)^2 \cdot \frac{8Q^4 M^2 [u^2+(1-u)^2]}{(Q^2+M^2)^6 u^2 (1-u)^2}.$$

$u = 0.5$:



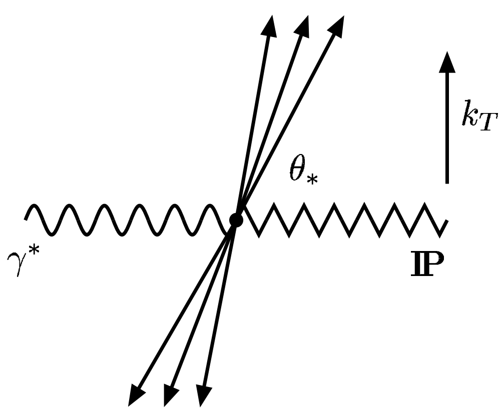
Kinematics of diffractive DIS



M_X: mass of the diffractive system

$x_{\mathrm{IP}} = \frac{M_X^2+Q^2}{W^2+Q^2}$: fraction of proton momentum carried by IP

$\beta = \frac{Q^2}{M_X^2+Q^2}$: fraction of IP momentum which enters the interaction



$u = \frac{1+\cos\theta^*}{2}$: Longitudinal momentum fraction

k_t: transverse momentum of jets in γ^*–IP CM frame

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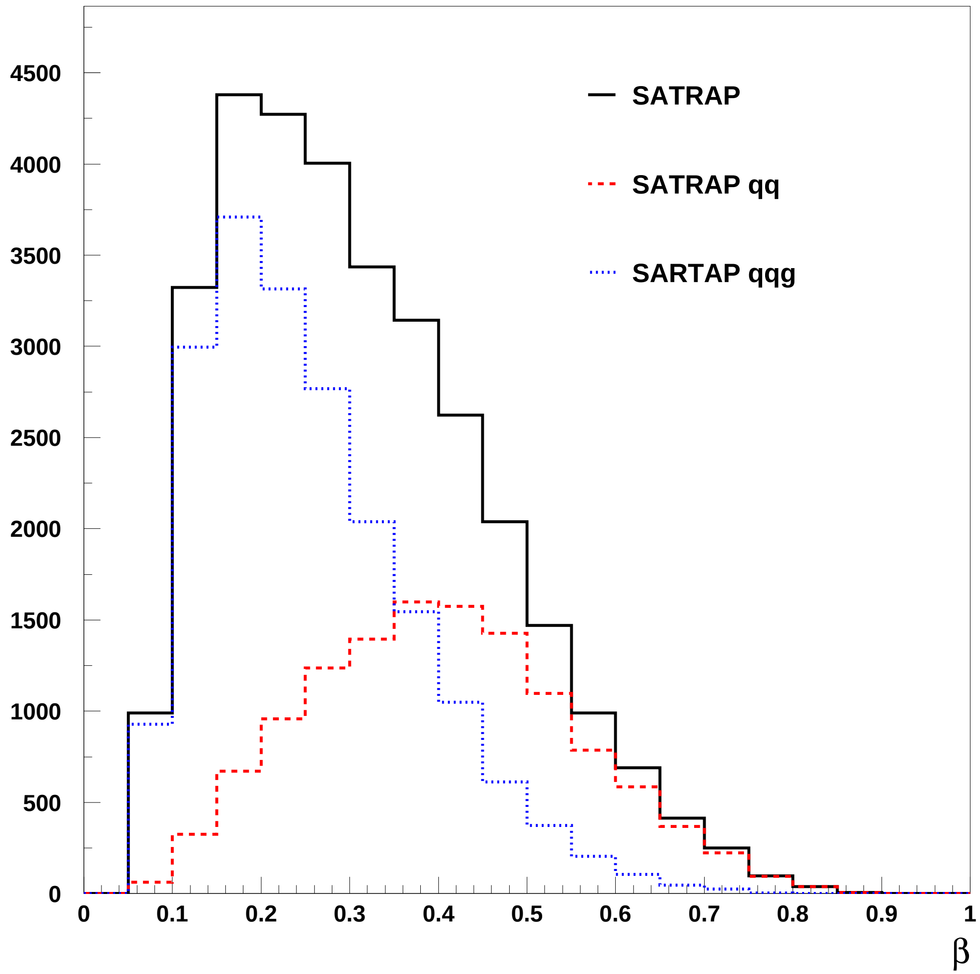
Selection of $q\bar{q}$ dijets using β :



For $\beta > 0.45$, 23% $q\bar{q}g$ background

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Event Selection for $\gamma^*\, p \rightarrow DJ$

- $E_{e'} > 10$ **GeV**
- **Proton did not disintegrate**
- **Jet identification with clustering algorithm**
- **Elasticity (only 2 jets in event)**
- **Various cleaning cuts**
- **Diffractive (small t)**
- $5 \leq M_{DJ} \leq 30GeV$
- $10 < Q^2 < 500GeV^2$
- $100 < W < 200\,GeV$
- $0.01 < y < 0.9$
- $k_t > 1.25GeV$
- $\beta > 0.45$**, Test by ϕ Angular Distribution**
- $0.1 < u < 0.9$
- $0.00001 < x_{\mathbb{P}} < 0.015$

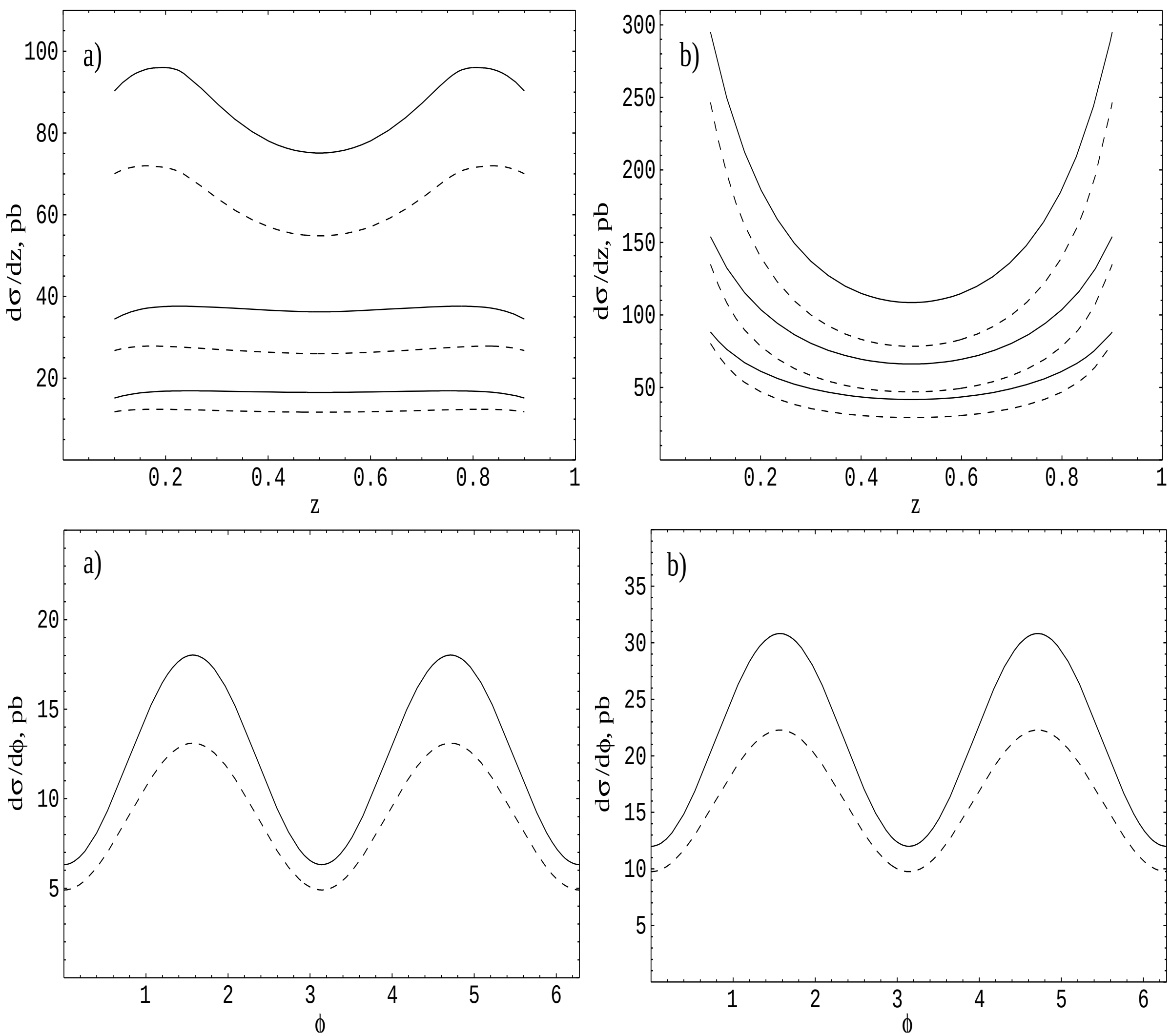
For experimental results....

stay tuned

Electroproduction: V.M. Braun and D.Yu. Ivanov, hep-ph/0505263

$k_\perp$=1.25, 1.5, 1.75 GeV/c; Solid: CTEQ6L, dashed: MRST2001LO

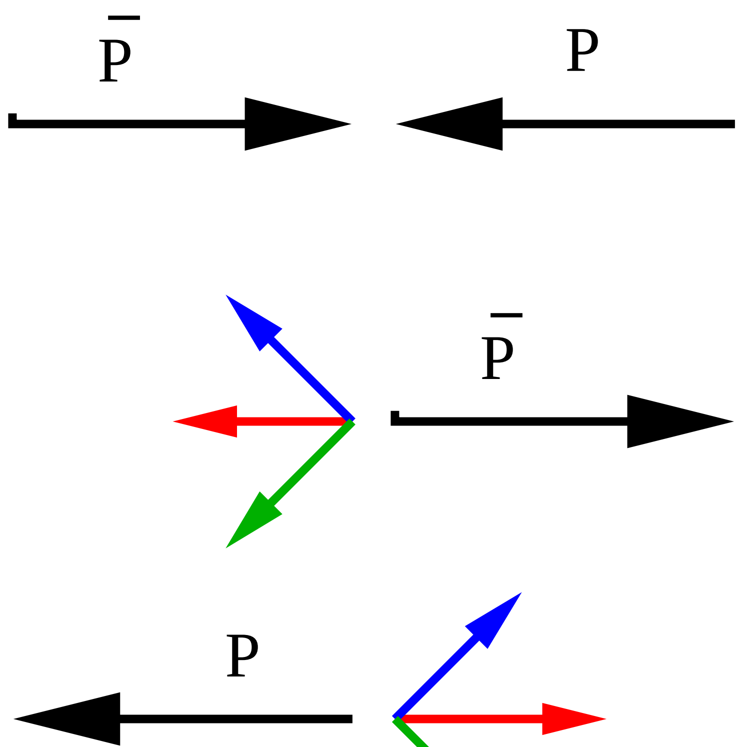
$\beta > 0.5$ $\beta > 0$



The Proton Light-Cone Wave Function

1. **HERA:** $p\ e \rightarrow 3J\ e'$

2. **Fermilab Collider:** $p\ \bar{p} \rightarrow 3J\ p$, **use Roman Pots.**



Summary

- **Diffractive dissociation of hadrons and photons can be used to study their internal quark structure.**

- **The momentum wave function of the $|q\bar{q}>$ in the pion is described well at $\mathbf{Q}^2 > 10\ GeV^2$ by the Asymptotic wave function.**

- **For lower Q^2 values the momentum wave function of the $|q\bar{q}>$ in the pion contains 2^{nd} and 4^{th} Gegenbauer Polynomials with coefficients: $a_2 = 0.30 \pm 0.05$, $a_4 = (0.5 \pm 0.1) \cdot 10^{-2}$.**

- Measurements of the photon electromagnetic light-cone wave functions are completed and the results are in agreement with QED.

- This provides the first proof that diffractive dissociation of particles can be reliably used to measure their light cone wave functions.

- **Measurements of the photon hadronic light-cone wave functions are in progress.**

- **Photon dissociation $\gamma^* \, p \rightarrow \pi^+\pi^- \, p$ is dominated by Longitudinal photons fluctuating to $q\bar{q}$. Charge asymmetry as signal of the Odderon being studied.**

- **Photon dissociation $\gamma^* \, p \rightarrow J \; J \; p$ is dominated by Transverse photons fluctuating to $q\bar{q}$ as observed in the azimuthal angular distribution.**