ABSORPTION PICTURE OF HARD DIFFRACTION DISSOCIATION: FACTORIZATION BREAKING

A. BIALAS

(1) REMINDER OF THE GOOD-WALKER IDEA

(2) CASE OF SMALL PERTURBATION

(3) MODEL OF INDEPENDENT PARTONS

(4) $\gamma^* \to$ JETS & $p \to p +$ JETS

(5) TWO-GAP, ONE-GAP, NO GAP

(6) SUMMARY

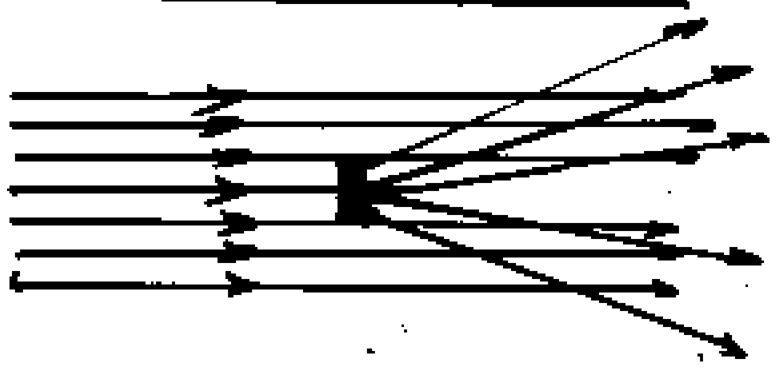
A.B. ACTA PHYS. POL. **B33** (2002) 2635.

R. PESCHANSKI & A.B. PHYS. LETT. B575 (2003) 30.

DIFFRACTIVE PROCESSES AT HIGH ENERGY

I. ELASTIC DIFFRACTION

(a) WAVE OPTICS



ABSORPTION OF THE INCIDENT WAVE IMPLIES DIFFRACTION, I.E. ELASTIC SCATTERING $\Rightarrow$ "SHADOW SCATTERING"

(b) QUANTUM MECHANICS

$$S\,|\psi_i\rangle = |\psi_f\rangle \qquad S = 1 - T$$

$$S^+S = 1 \Rightarrow \quad 2\langle\psi_i|T|\psi_i\rangle = \sum_n |\langle n|T|\psi_i\rangle|^2$$

$\Rightarrow$ "OPTICAL THEOREM" $\qquad 2T(0) \sim \sigma_{TOT}$

INELASTIC COLLISIONS

INDUCE ELASTIC SCATTERING

DIFFRACTION!

GOOD - WALKER DECOMPOSITION

$$|\psi\rangle = \sum c_n |\hat{\psi}_n\rangle \qquad \underline{T|\hat{\psi}_n\rangle = t_n |\hat{\psi}_n\rangle}$$

"DIFFRACTIVE" STATES

ELASTIC SCATTERING : $\langle\psi|T|\psi\rangle = \sum_n |c_n|^2 t_n = \langle t\rangle$

DISSOCIATION: $|\psi'\rangle = \sum_n c'_n |\hat{\psi}_n\rangle ; \quad \sum \overline{c'_n}\, c_n = 0$

$\langle\psi'|T|\psi\rangle = \sum_n \overline{c'_n}\, c_n\, t_n$ ⟵ COMPLICATED SUPERPOSITION

COMPLEX PHASES NEEDED

$$\underline{\sigma^{DIFF}} = \sum_{\psi'} \left|\langle\psi'|T|\psi\rangle\right|^2 = \sum |c_n|^2 t_n^2 = \langle t^2\rangle$$

TOTAL DIFFRACTIVE CROSS - SECTION

CASE OF SMALL PERTURBATION

$$|\psi\rangle = |\hat{\psi}_0\rangle + \epsilon\,|\hat{\psi}_1\rangle + \cdots$$

$$|\tilde{\psi}\rangle = -\bar{\epsilon}\,|\hat{\psi}_0\rangle + |\hat{\psi}_1\rangle + \cdots$$

PUMPLIN
ROSS
KOTANSKI, CZYZ, AB '72

$$\langle\tilde{\psi}|\psi\rangle = 0 \qquad \langle\hat{\psi}_1|\hat{\psi}_0\rangle = 0$$

$$\boxed{\langle\hat{\psi}_1|T|\hat{\psi}_0\rangle = 0}$$

ELASTIC:

$$\langle\psi|T|\psi\rangle = \langle\hat{\psi}_0|T|\hat{\psi}_0\rangle + O(\epsilon^2)$$

$$\langle\tilde{\psi}|T|\tilde{\psi}\rangle = \langle\hat{\psi}_1|T|\hat{\psi}_1\rangle + O(\epsilon^2)$$

DISSOCIATION:

$$\underline{\langle\tilde{\psi}|T|\psi\rangle} = \epsilon\left[\langle\hat{\psi}_1|T|\hat{\psi}_1\rangle - \langle\hat{\psi}_0|T|\hat{\psi}_0\rangle\right] + O(\epsilon^2) =$$

$$= \underline{\epsilon\left[\langle\tilde{\psi}|T|\tilde{\psi}\rangle - \langle\psi|T|\psi\rangle\right]} + O(\epsilon^2)$$

AMPLITUDE FOR DISSOCIATION IS PROPORTIONAL TO THE DIFFERENCE OF ELASTIC AMPLITUDES IN THE FINAL AND INITIAL STATES

PARTON MODEL: DIFFRACTIVE STATES ARE STATES WITH A FIXED NUMBER & (TRANSVERSE) POSITIONS OF PARTONS

(FIALKOWSKI & VAN HOVE; MIETTINEN & PUMPLIN)

HERA: $\gamma^* \longrightarrow$ JETS ...

NO PARTONS

HARD $q\bar{q}$ DIPOLE + SOFT PARTONS

$$|\gamma^*\rangle = |0\rangle + \epsilon\,|D^*\rangle$$

GOOD-WALKER DECOMPOSITION

$$|\text{JETS}\rangle = -\bar{\epsilon}|0\rangle + |D^*\rangle$$

$$\langle \text{JETS}|T|\gamma^*\rangle = \epsilon\left[\langle D^*|T|D^*\rangle - \underbrace{\langle 0|T|0\rangle}_{=0}\right] = \epsilon\,\langle D^*|T|D^*\rangle$$

STODOLSKY

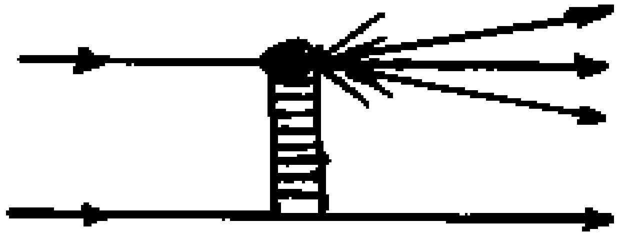
GOTTFRIED & YENNIE

CHAKRAI & SCHILDKNECHT

$$|\langle \text{JETS}|T|\gamma^*\rangle|^2 = |\epsilon|^2\,\sigma_{D^*}^{DIFF}$$

SINGLE DIFFRACTION AT FERMILAB

$p \to p + \text{JETS}$



$|p\rangle = |g\rangle + \epsilon\, |g + D^*\rangle$ $\qquad$ $\langle p|T|p\rangle = \langle g|T|g\rangle \equiv T_p$

$|p + J^*\rangle = -\bar{\epsilon}\, |g\rangle + |g + D^*\rangle$ $\qquad$ $\langle p + J^*|T|p\rangle = \epsilon\left[\langle g+D^*|T|g+D^*\rangle - \langle g|T|g\rangle\right]$

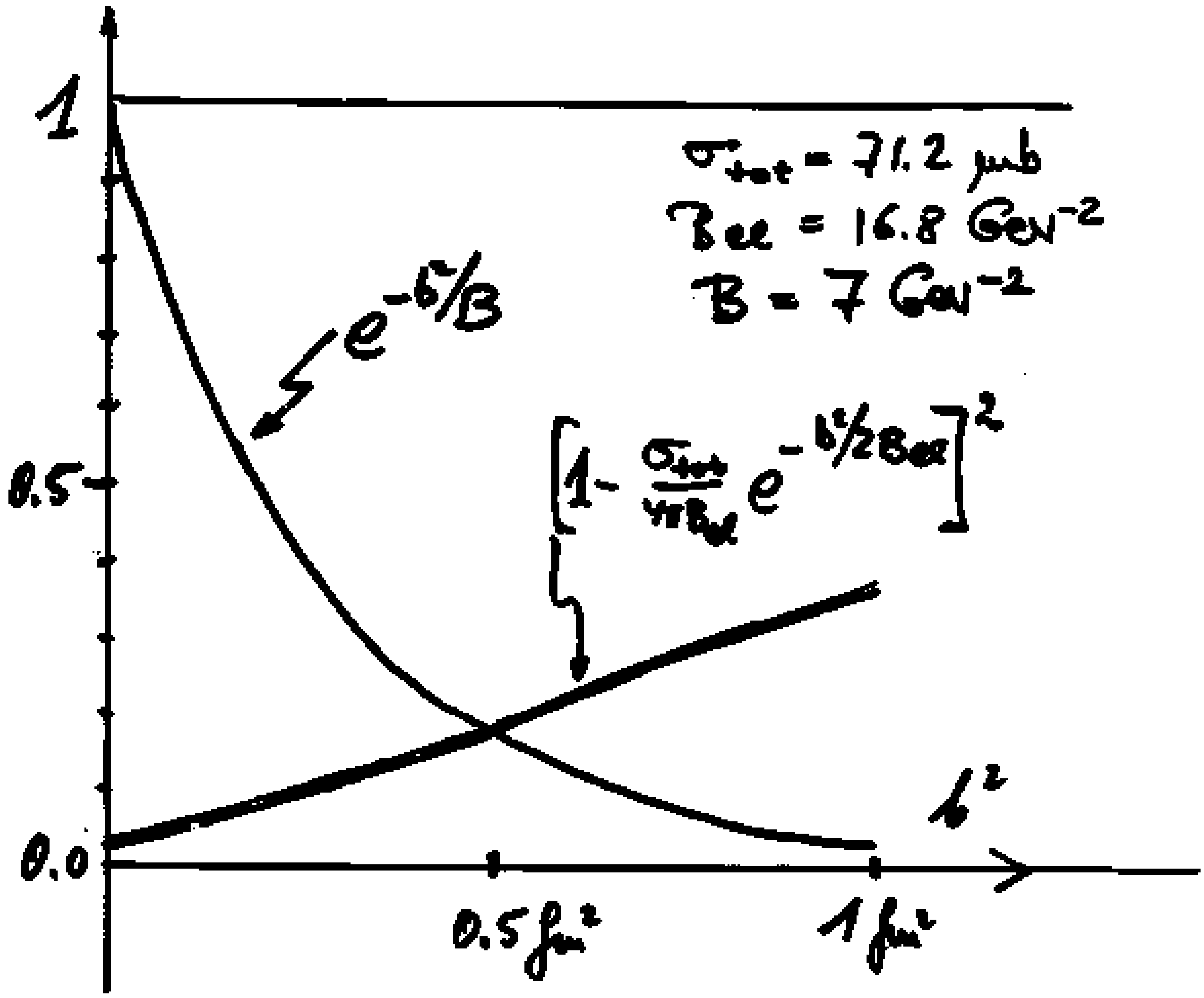
INDEPENDENT INTERACTIONS: $\rightarrow$ $1 - \langle g+D^*|T|g+D^*\rangle = (1 - \langle D^*|T|D^*\rangle)(1 - \langle g|T|g\rangle)$

$$\langle g+D^*|T|g+D^*\rangle - \langle g|T|g\rangle = \langle D^*|T|D^*\rangle \left[1 - \langle g|T|g\rangle\right]$$

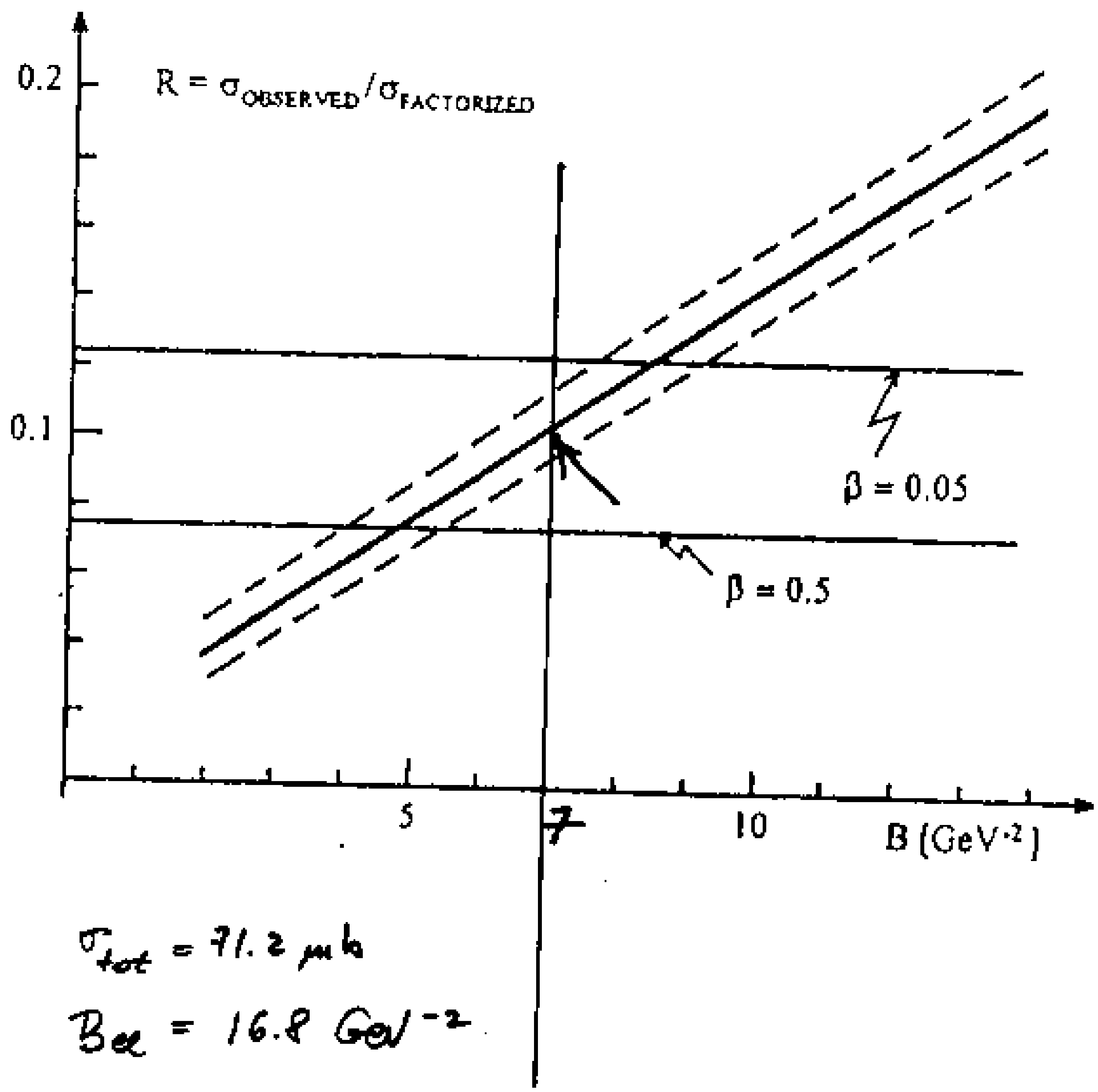
$$\left|\langle p+J^*|T|p\rangle\right|^2 = |\epsilon|^2\, \sigma_{D^*}^{DIFF} \left[1 - T_p\right]^2 \Leftarrow$$ FACTORIZATION BREAKING

HERA: $\left|\langle J^*|T|\gamma\rangle\right|^2 = |\epsilon|^2\, \sigma_{D^*}^{DIFF}$

CORRECTION FACTOR VS IMPACT PARAMETER



FACTORIZATION BREAKING – NUMERICAL ESTIMATE



$\sigma_{tot} = 71.2\ \mu b$

$B_{el} = 16.8\ GeV^{-2}$

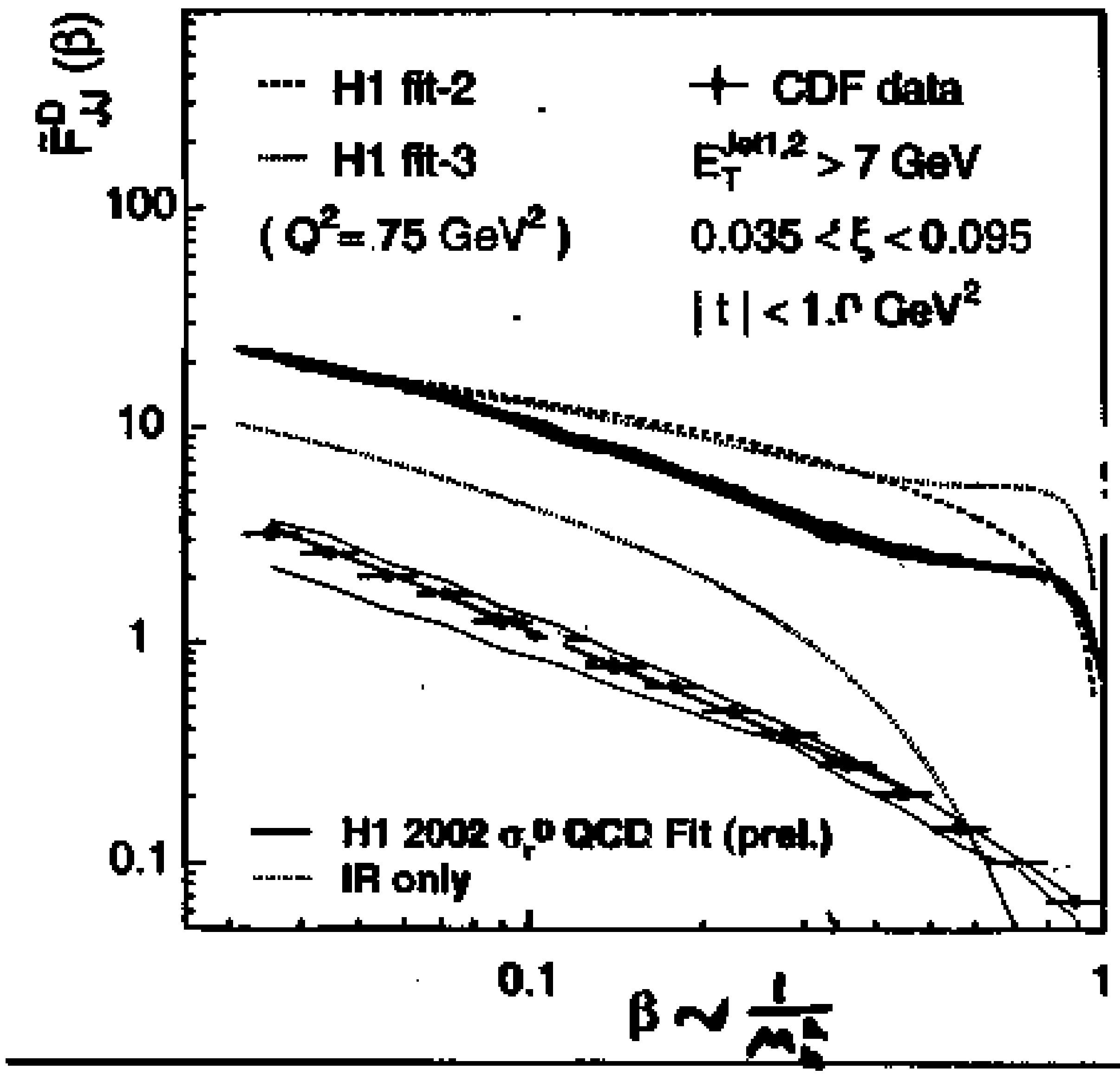
$B = 7\ GeV^{-2}$

Comparison with CDF diffractive Dijet cross sections

Dijet production with tagged leading anti-proton at TEVATRON: PRL 84 (2000) 5043

Effective diffractive structure function $\tilde{F}_{jj}^{D}$:

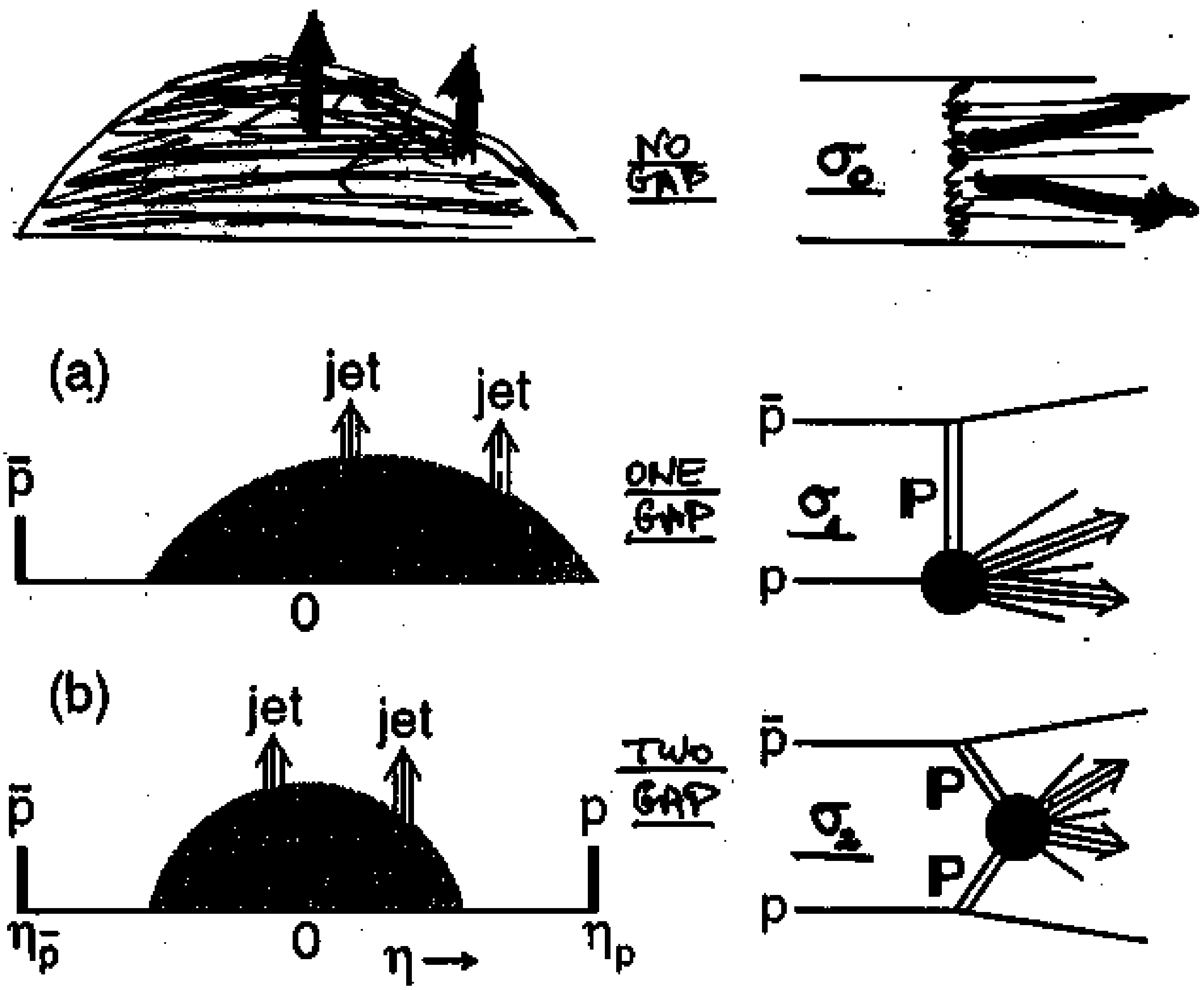
$$\tilde{F}_{jj}^{D}(\beta) = \int dx_{\mathbb{P}} dt f(x_{\mathbb{P}}, t)\ \beta\left[g(\beta, Q^2) + \tfrac{4}{9}\Sigma(\beta, Q^2)\right] \qquad (Q^2 = 75\ GeV^2)$$

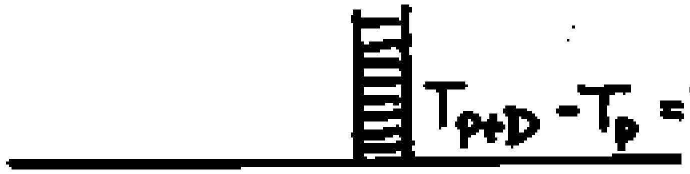


- **New fit confirms serious breakdown of factorization**
- **β dependence similar (except highest β)**
- **NOTE $x_{\mathbb{P}}$ domain: 50% contribution from subleading quark exchange in this kinematic regime**

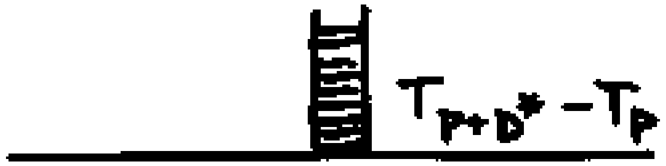
DATA: $\sigma_2/\sigma_1 \gg \sigma_1/\sigma_0$

FACTORIZATION BREAKING





$$T_{P+D} - T_P = T_D(1-T_P)$$

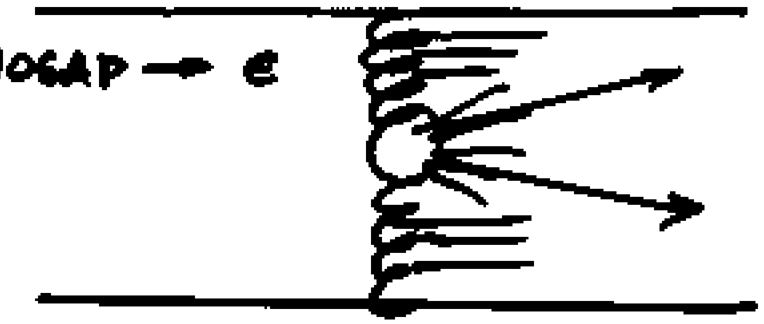


$$T_{P+D^*} - T_P = T_{D^*}(1-T_P)$$

$$\underline{\sigma_2} = |\epsilon_P|^2 \, \sigma_D^{DIFF} (1-T_P)^2$$

$$\underline{\sigma_1} = |\epsilon|^2 \sigma_{D^*}^{DIFF} (1-T_P)^2 = |\epsilon_P|^2 \sigma_D^{NONDIFF} \left[1-T_P\right]^2$$

NOGAP → ϵ



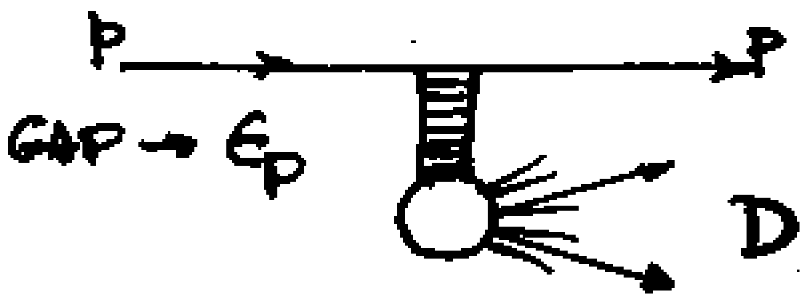
$$\underline{\sigma_0} = |\epsilon|^2 \, \sigma_{D^*}^{NONDIFF} = |\epsilon_P|^2 \, \sigma_D^{NONDIFF} \, \frac{\sigma_{D^*}^{NONDIFF}}{\sigma_{D^*}^{DIFF}}$$

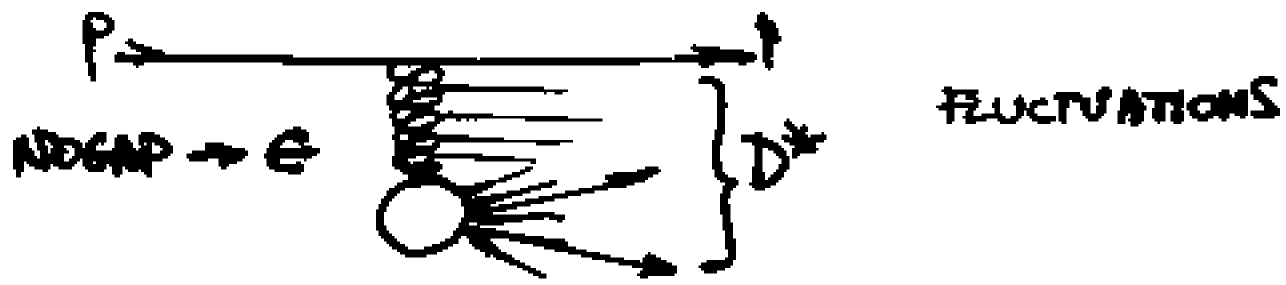
$$\frac{\sigma_2}{\sigma_1} = \frac{\sigma_D^{DIFF}}{\sigma_D^{NONDIFF}}$$

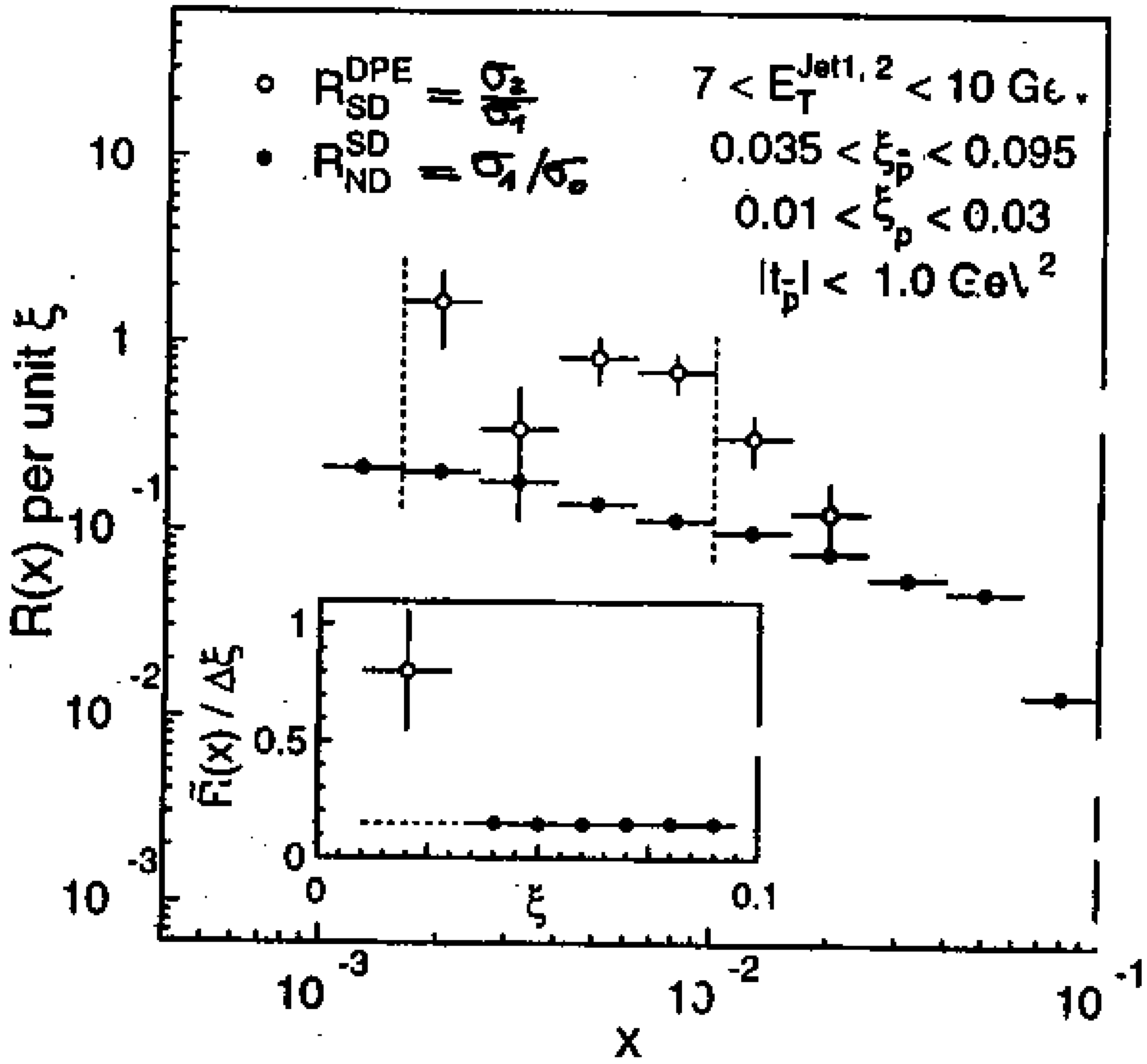
FACTORIZATION BREAKING

$$\frac{\sigma_1}{\sigma_0} = \frac{\sigma_{D^*}^{DIFF}}{\sigma_{D^*}^{NONDIFF}} \left(1-T_P\right)^2$$

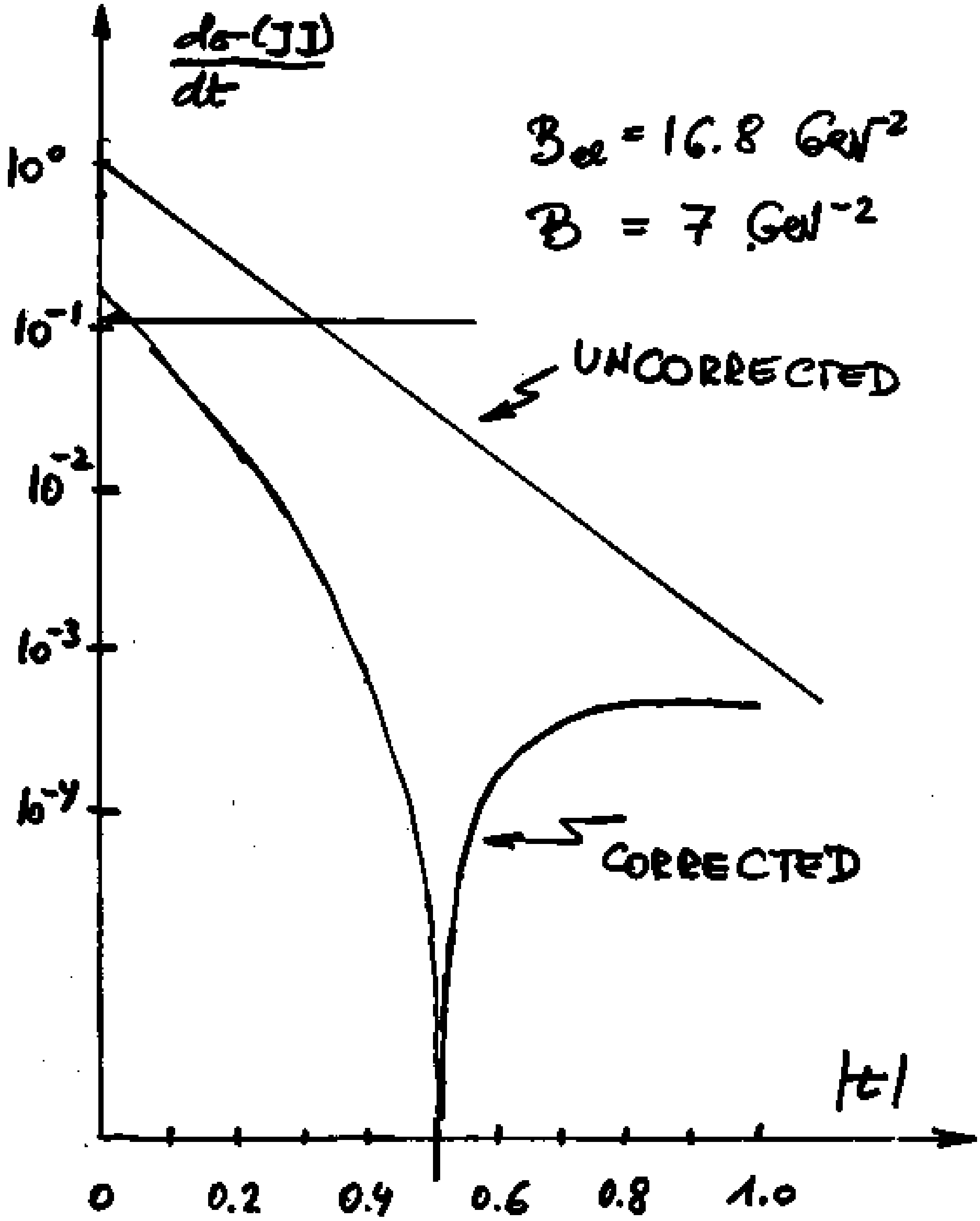
TWO-GAP, ONE-GAP, ZERO-GAP : FACTORIZATION BREAKING







$R_{SD}^{DPE} = \frac{\sigma_2}{\sigma_1}$
$R_{ND}^{SD} = \sigma_1/\sigma_0$
$7 < E_T^{Jet1,2} < 10$ GeV
$0.035 < \xi_{\bar{p}} < 0.095$
$0.01 < \xi_p < 0.03$
$|t_{\bar{p}}| < 1.0$ GeV^2
R(x) per unit ξ
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-3}
10^{-2}
10^{-1}
x
$\tilde{R}(x) / \Delta\xi$
1
0.5
0
0
0.1
ξ



$\frac{d\sigma(JJ)}{dt}$
$B_{el} = 16.8\ GeV^{-2}$
$B = 7\ GeV^{-2}$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
UNCORRECTED
CORRECTED
$|t|$
0
0.2
0.4
0.6
0.8
1.0

SUMMARY

(i) HARD DIFFRACTION DISSOCIATION CAN BE UNDERSTOOD AS A RESULT OF ABSORPTION OF THE INCIDENT BEAM.

(ii) FACTORIZATION BREAKING BETWEEN PHOTON - INDUCED & HADRON-INDUCED PROCESSES IS NATURALLY EXPLAINED.

(iii) THE SAME MECHANISM IS RESPONSIBLE FOR THE FACTORIZATION BREAKING OBSERVED IN FERMILAB DATA.

(iv) A STRUCTURE IN MOMENTUM TRANSFER DEPENDENCE MAY BE EXPECTED.