Factorization Breaking in Diffraction

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Contents

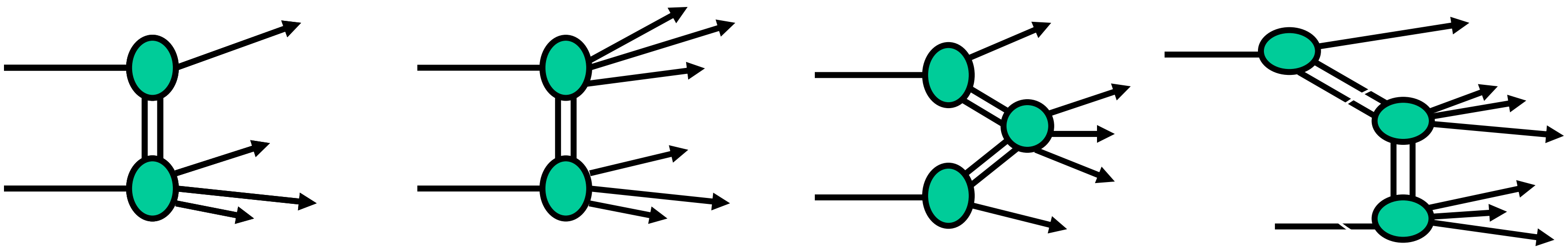
- pp and $\bar{p}$p results
- γp and γ^*p results
- renormalization:

the common thread

pp and $\bar{p}$p results

…many $\bar{p}p$ results from CDF!

Gaps in soft and hard processes

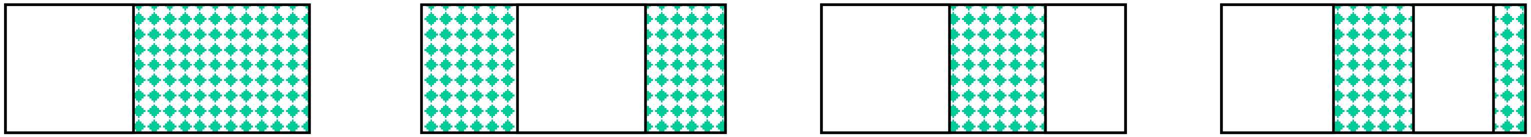


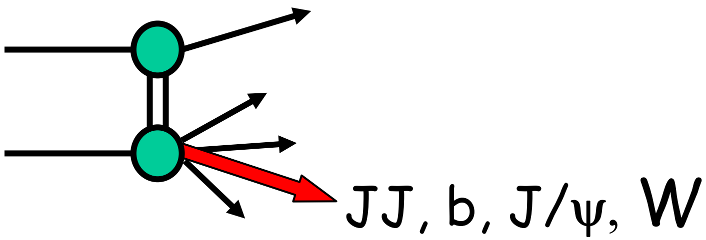
Single **D**iffraction dissociation (**SD**)

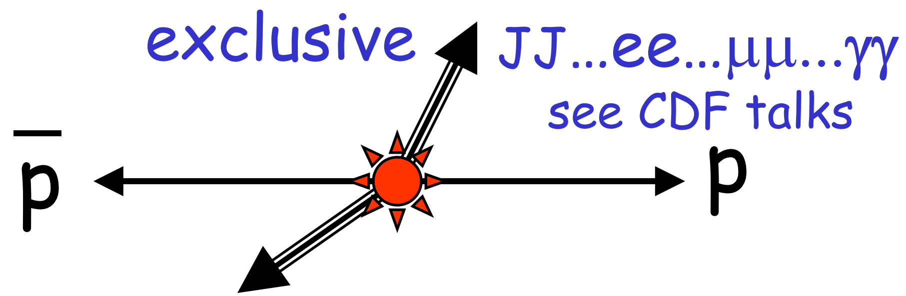
Double **D**iffraction dissociation (**DD**)

Double **P**omeron **E**xchange (**DPE**)

Single + **D**ouble **D**iffraction (**SDD**)

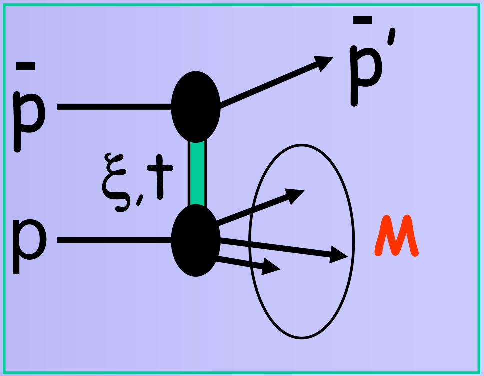




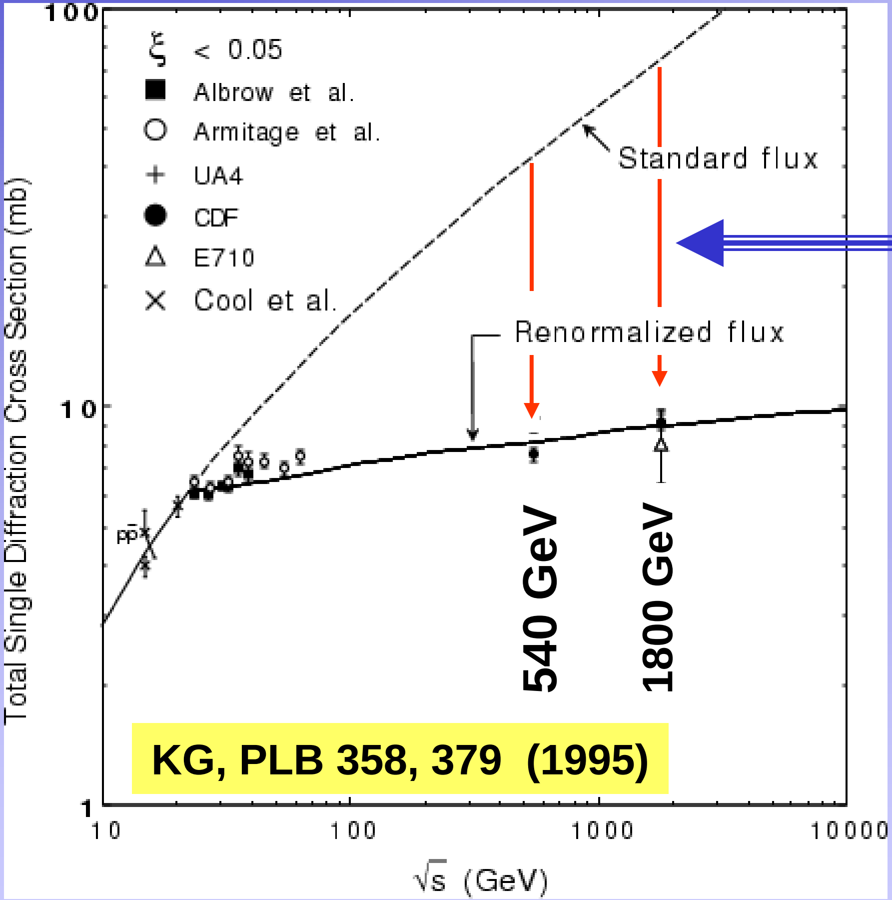


σ^T_{SD} (pp & $\bar{p}$p)

➔ suppressed relative Regge prediction



σ^T_{SD} mb



Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

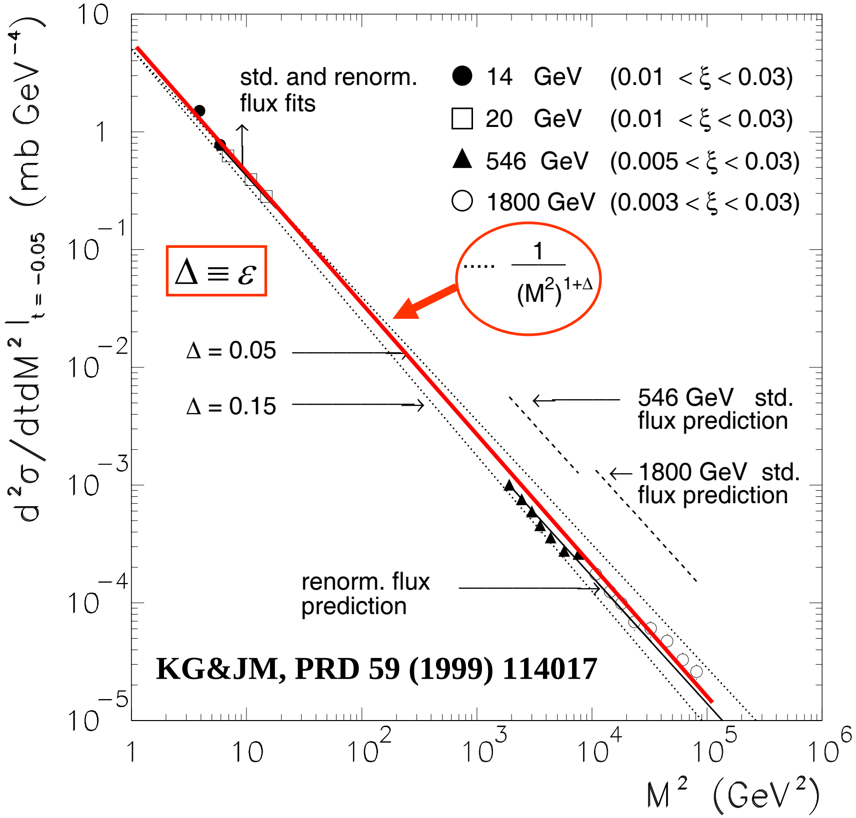
M^2 scaling

➔ ds/dM^2 independent of s over 6 orders of magnitude!

renormalization

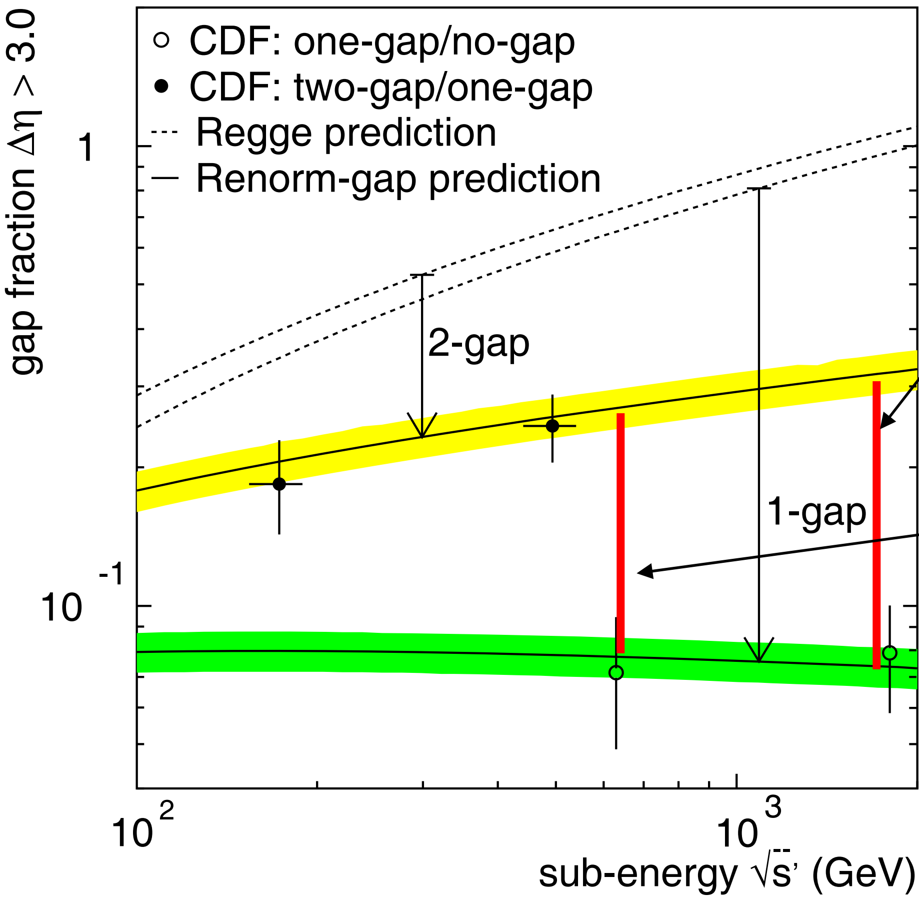
$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\varepsilon} \rightarrow 1}{(M^2)^{1+\varepsilon}}$$

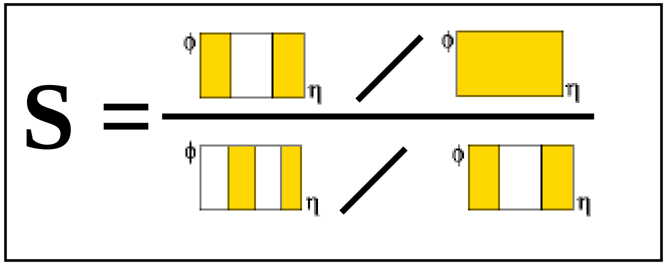
➔ Independent of S over 6 orders of magnitude in M^2!



➔ factorization breaks down to ensure M^2 scaling!

Gap Survival Probability - S

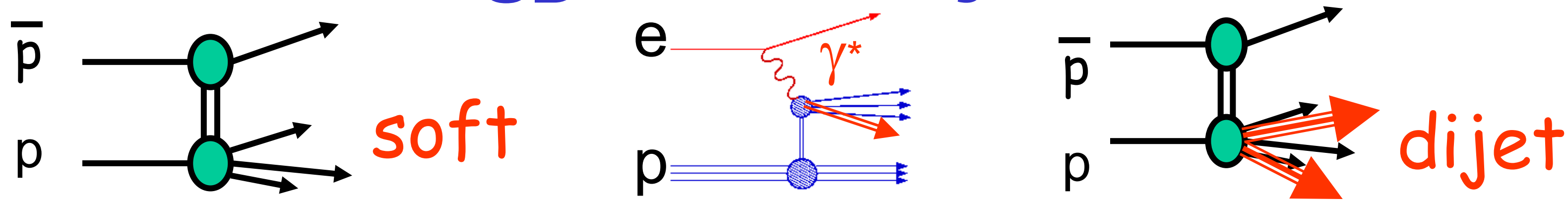


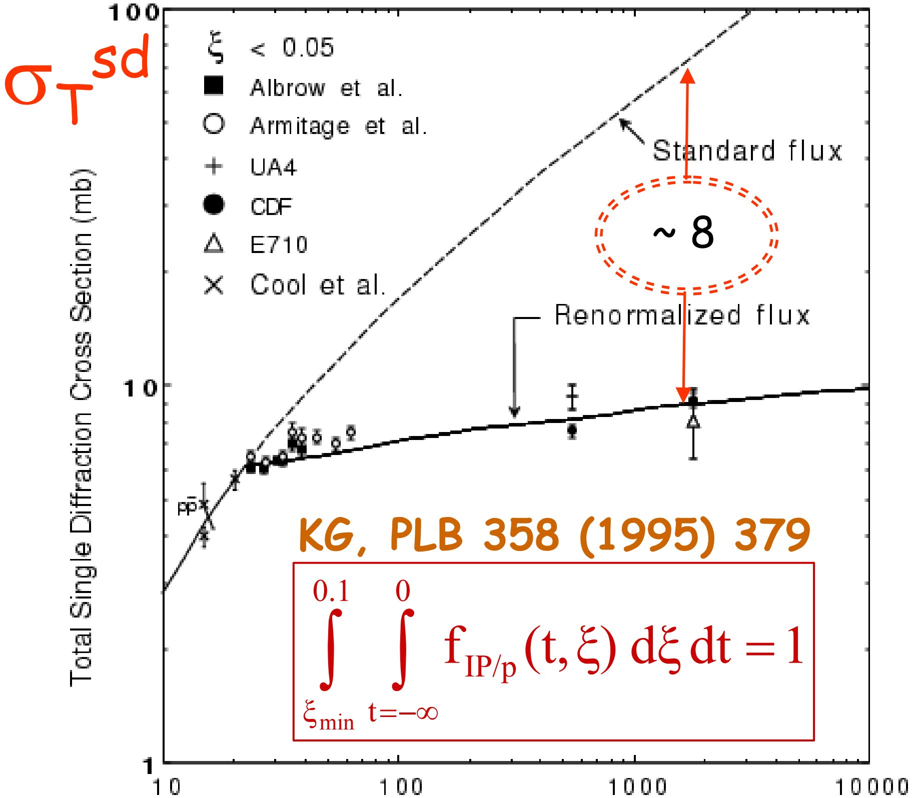


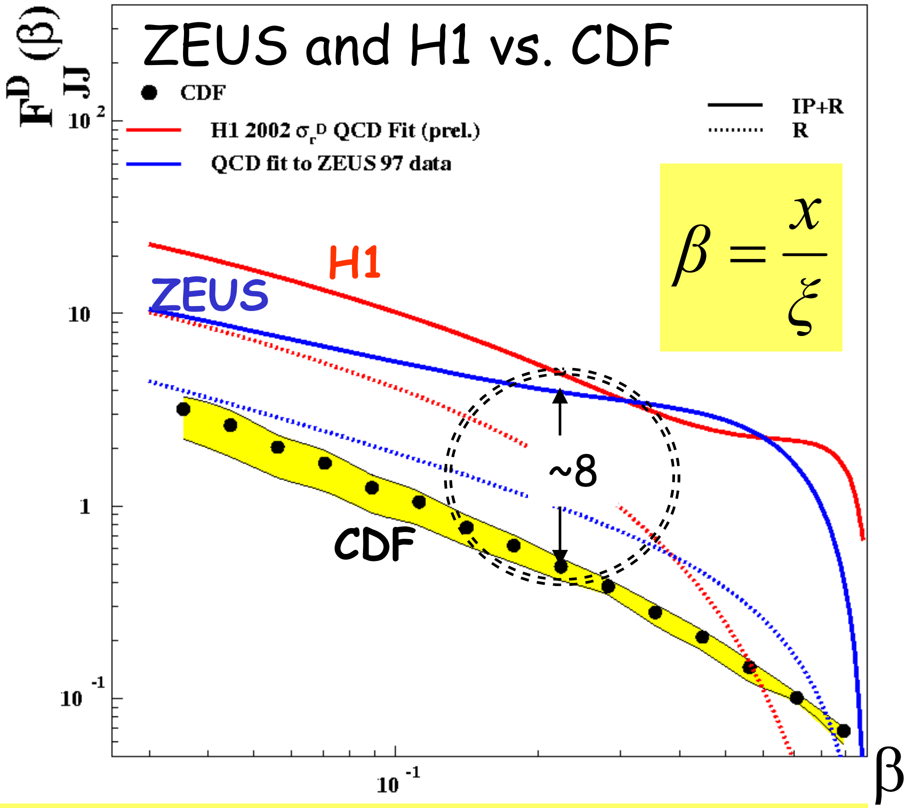
$S^{1-gap/0-gap}_{2-gap/1-gap}(1800\ \mathrm{GeV}) \approx 0.23$

$S^{1-gap/0-gap}_{2-gap/1-gap}(630\ \mathrm{GeV}) \approx 0.29$

σ^T_{SD} and dijets

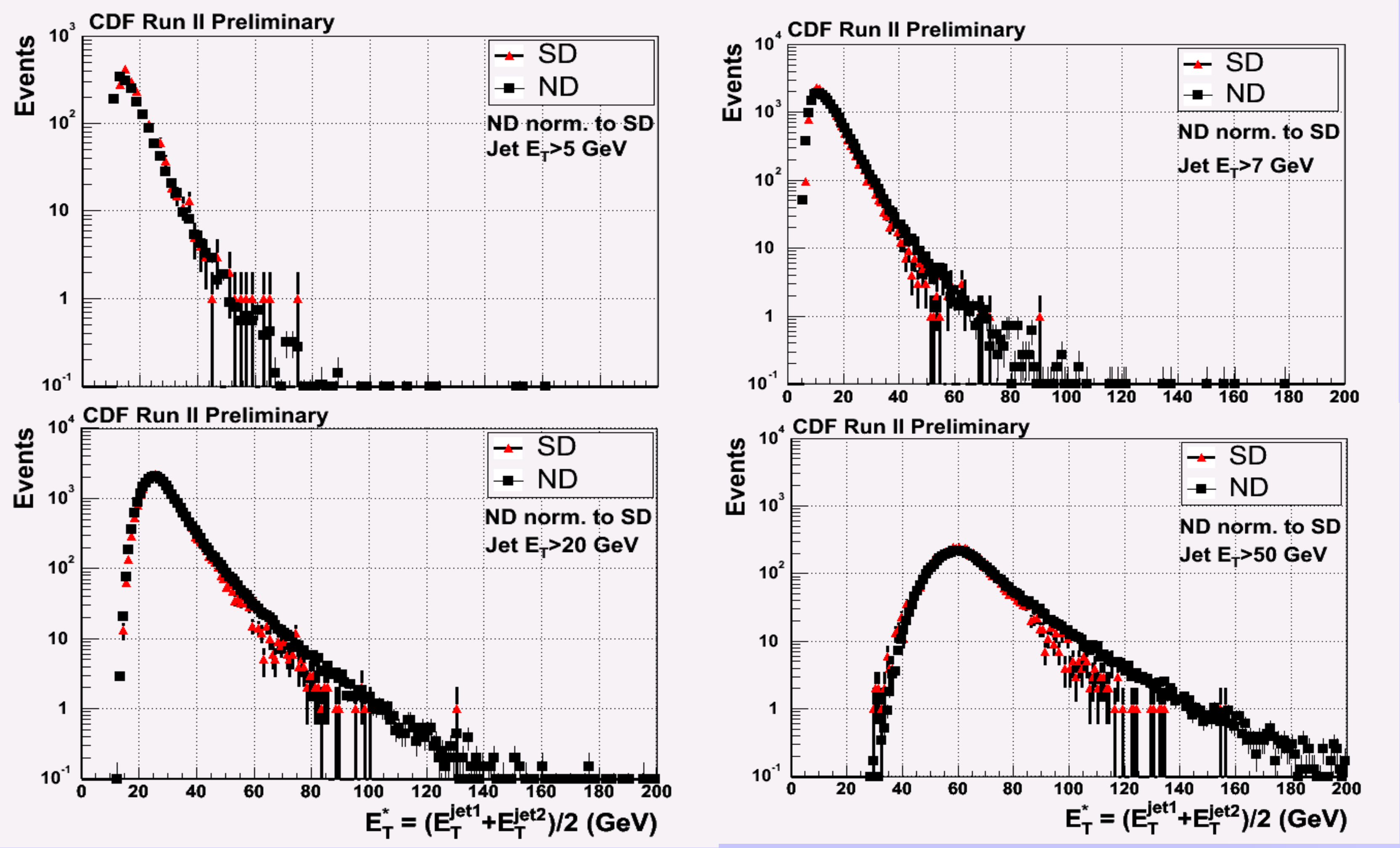






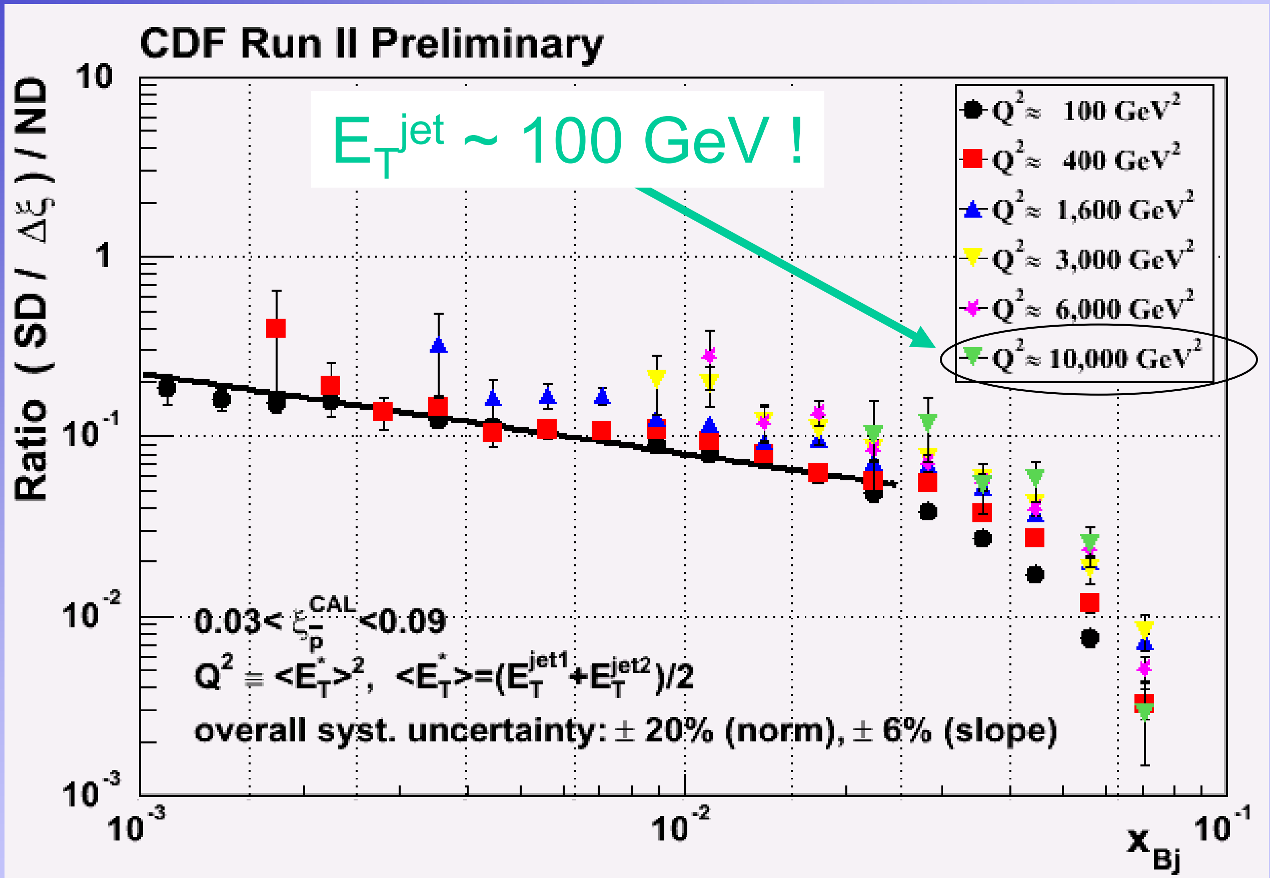
Magnitude: same suppression factor in soft and hard diffraction!
Shape of β distribution: ZEUS, H1, and Tevatron – why different slapes?

Dijets - E_T distribution



➔ similar for SD and ND over 4 orders of magnitude

Dijets-Diffractive Structure Function
x_{Bj} and Q^2 dependence

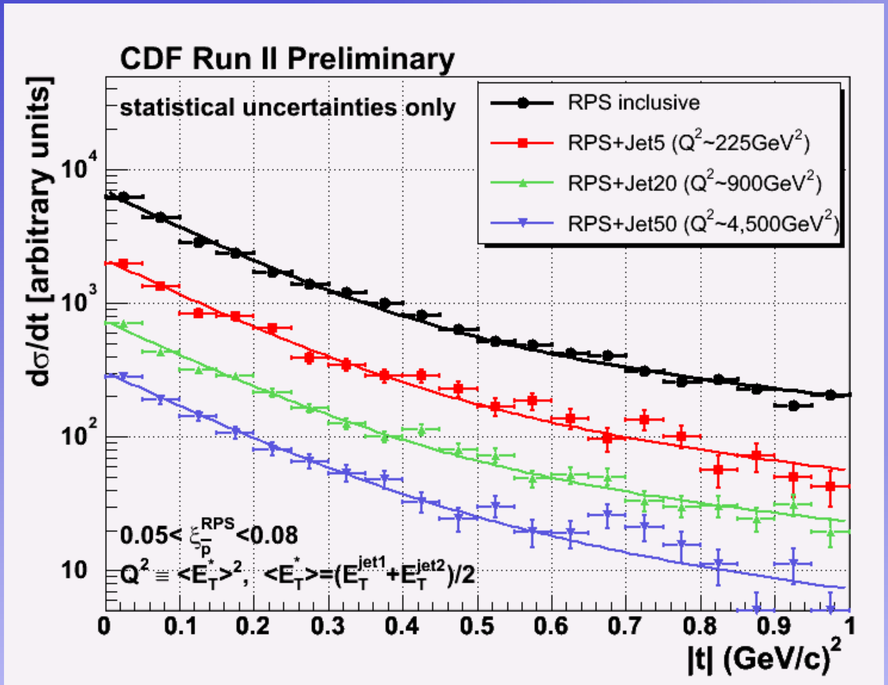


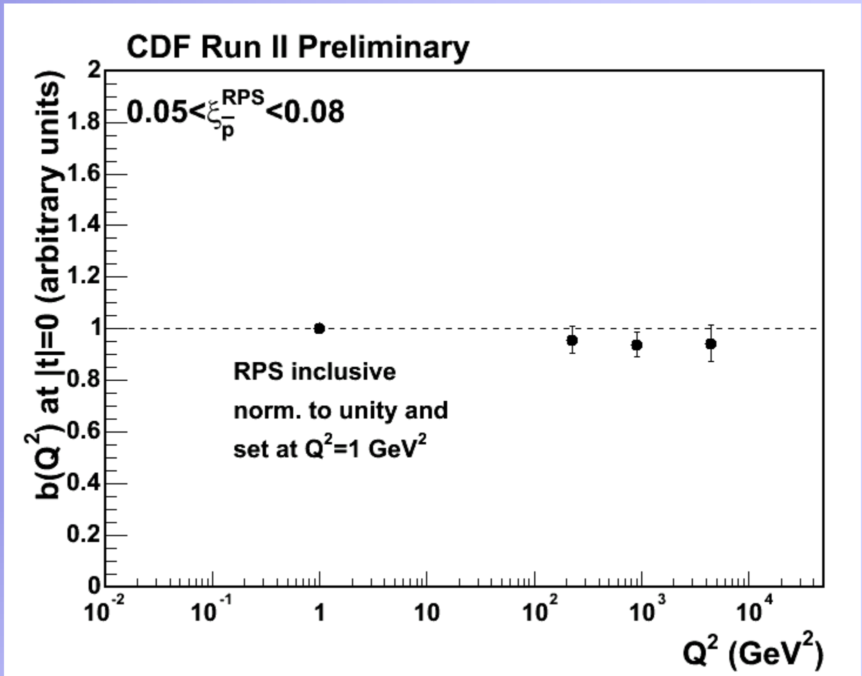
Small Q^2 dependence in region $100 < Q^2 < 10{,}000$ GeV^2

⇨ Pomeron evolves as the proton!

Dijets - Diffractive Structure Function

t- dependence





Fit dσ/dt to a double exponential

$$F = 0.9 \cdot e^{b_1 \cdot t} + 0.1 \cdot e^{b_2 \cdot t}$$

- No Q2 dependence in slope from inclusive to $Q^2 \sim 10^4$ GeV^2

- Same slope over entire region of $\sim 1 < Q^2 < 4{,}500$ GeV^2

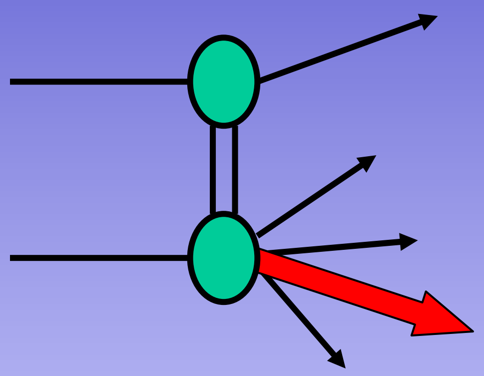
Hard diffractive fractions

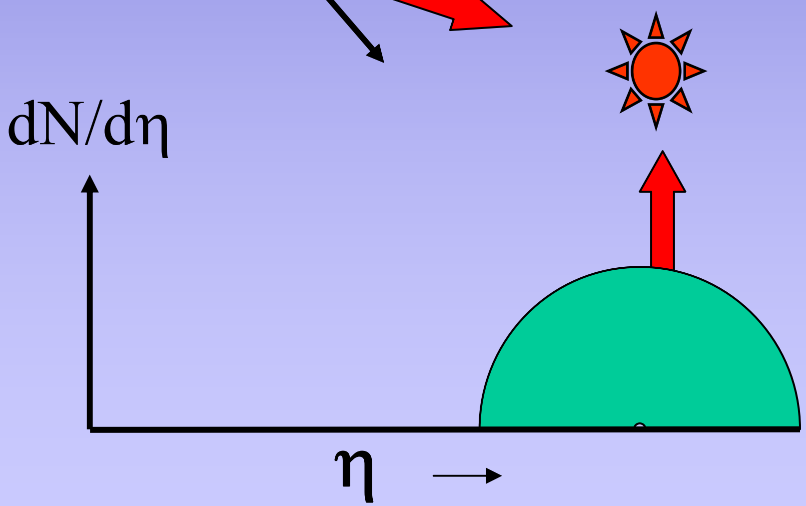
$$\bar{p}p \rightarrow (\star + X) + \text{gap}$$

Fraction: SD/ND
@ 1800 GeV

Run I

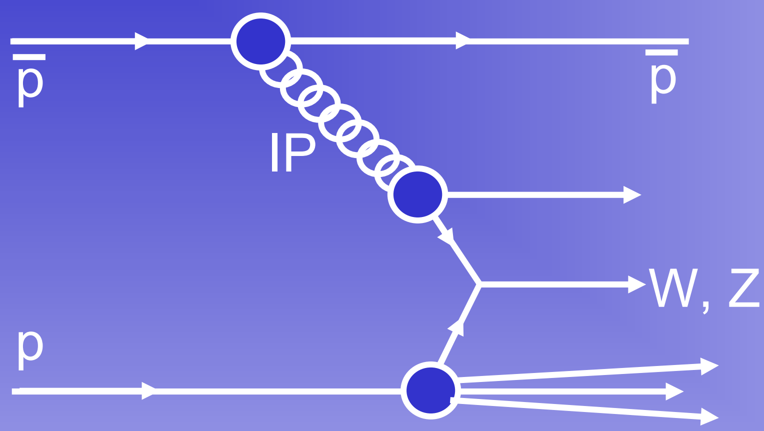
$\star$	Fraction (%)
JJ	0.75 +/- 0.10
W	0.115 +/- 0.55
b	0.62 +/- 0.25
J/ψ	1.45 +/- 0.25

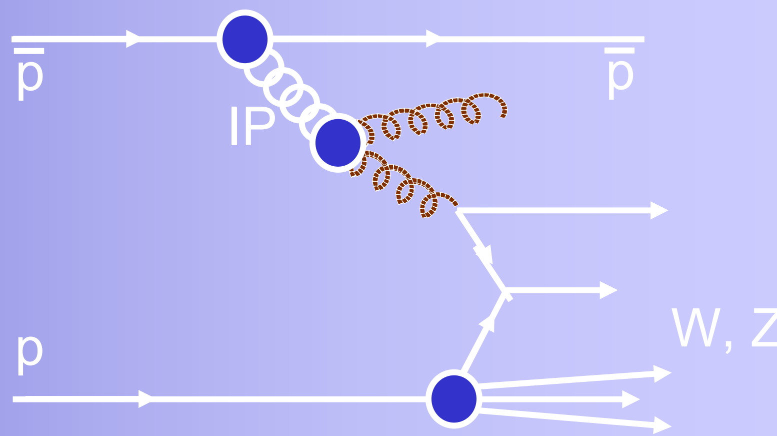




All fractions ~ 1%
(differences due to kinematics)
- ~ uniform suppression
- ~ FACTORIZATION ! !

Diffractive W/Z production - Run II





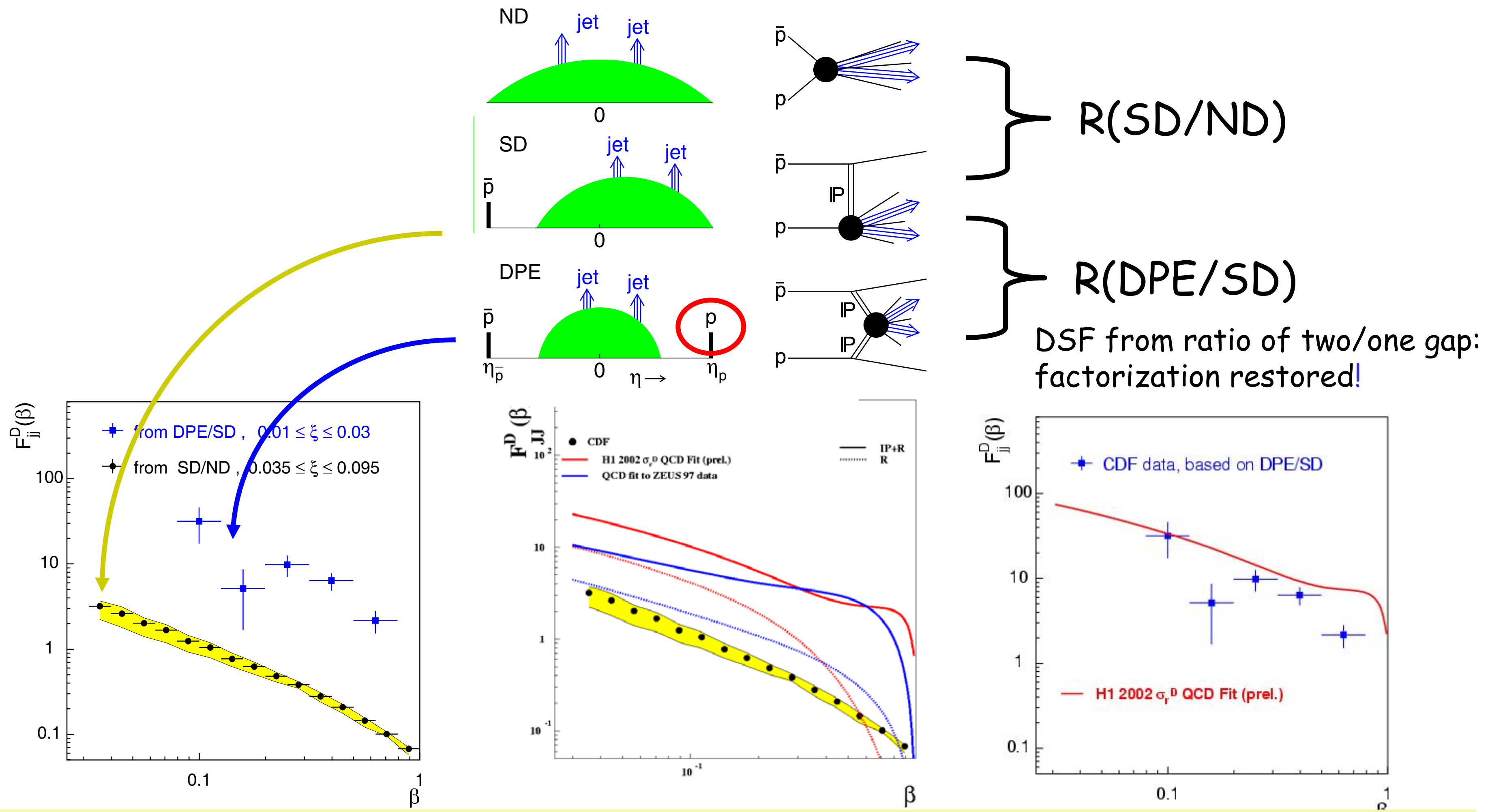
- Diffractive W production probes the quark content of the Pomeron
- Production by gluons is suppressed by a factor of α_S

$R^W(0.03 < \xi < 0.10, |t|<1) = [0.97 \pm 0.05(stat) \pm 0.11(syst)]\%$

Run I: $R^W = 1.15 \pm 0.55$ % for $\xi<0.1$ ➔ estimate **0.97±0.47 % in 0.03 < ξ < 0.10 & |t|<1)**

$R^Z(0.03 < x < 0.10, |t|<1) = [0.85 \pm 0.20(stat) \pm 0.11(syst)]\%$

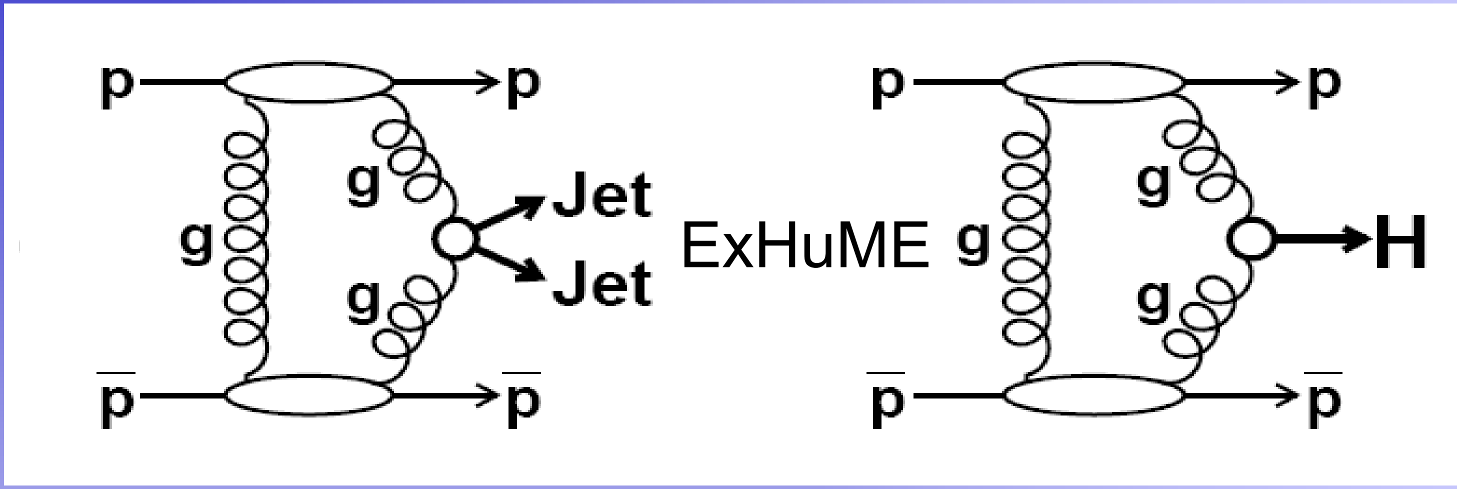
Multi-gap dijets - factorization restored!



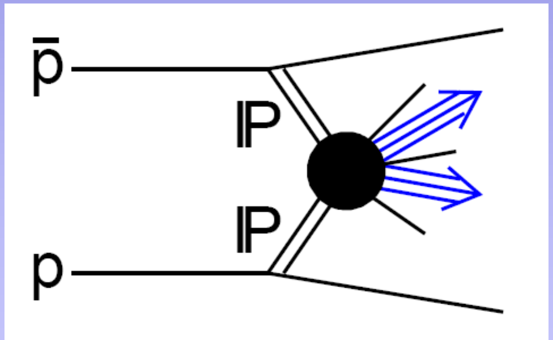
The diffractive structure function measured on the proton side in events with a leading antiproton is NOT suppressed relative to predictions based on DDIS

Exclusive Dijet and Higgs Production

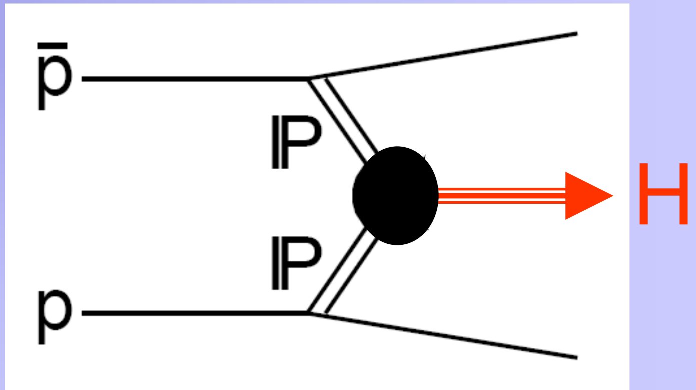
Phys. Rev. D 77, 052004



ExHuME

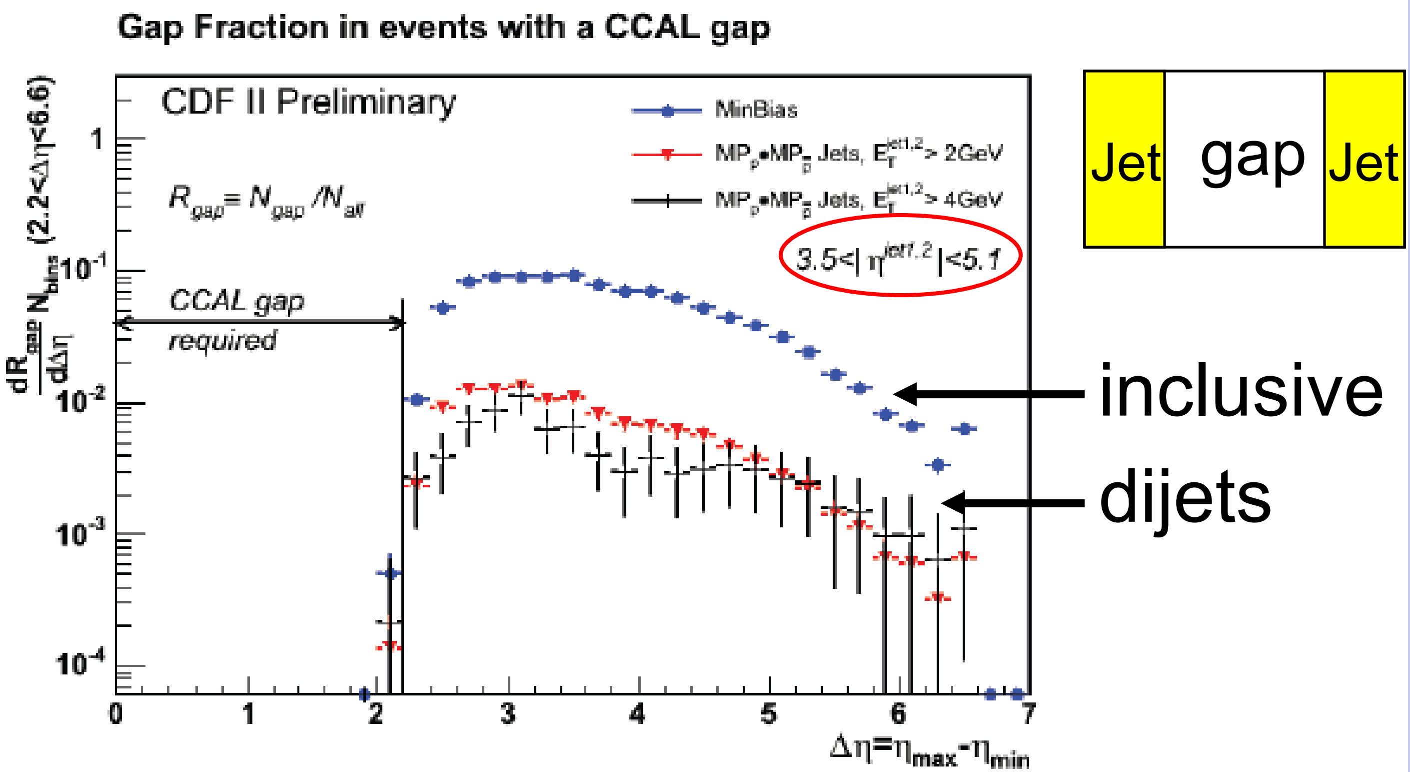


DPEMC



suppression factor ~50

Central gaps



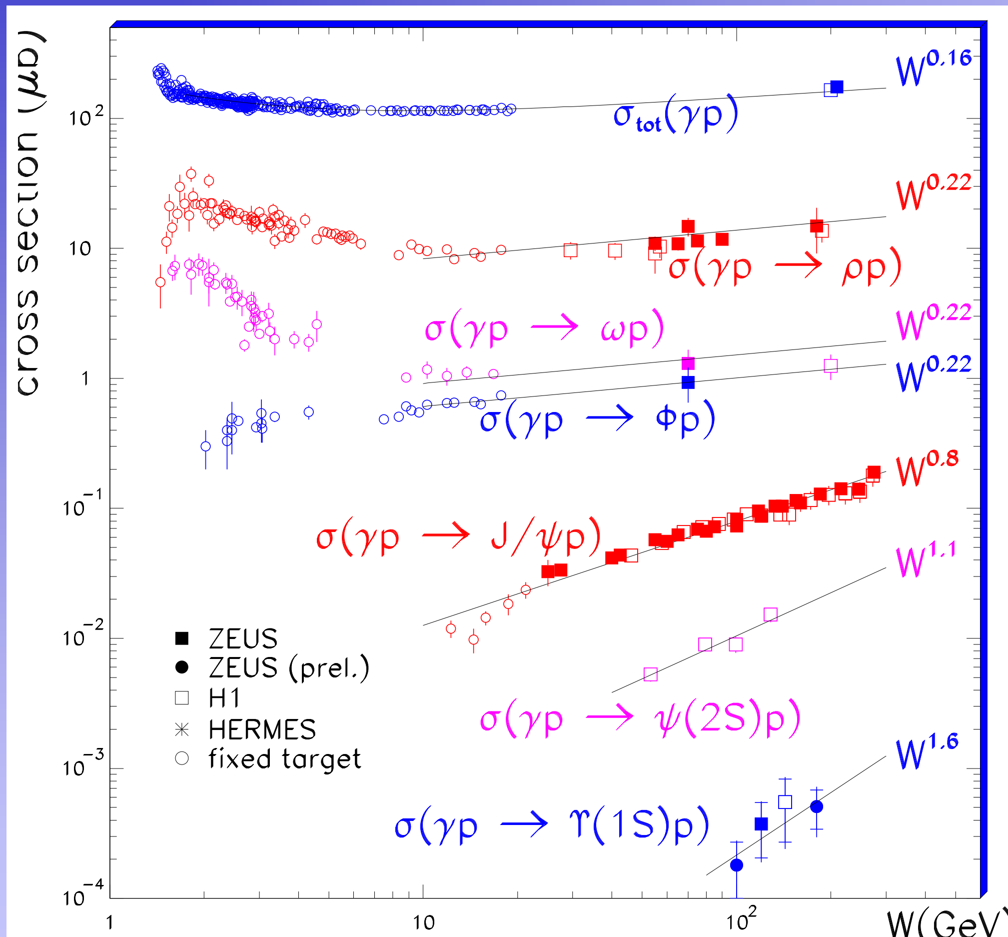
The distribution of the gap fraction $R_{gap}=N_{gap}/N_{all}$ vs $\Delta\eta$ for MinBias ($CLC_p \bullet CLC_{pbar}$) and MiniPlug jet events ($MP_p \bullet MP_{pbar}$) of $E_{T(jet1,2)}$>2 GeV and $E_{T(jet1,2)}$> 4 GeV.

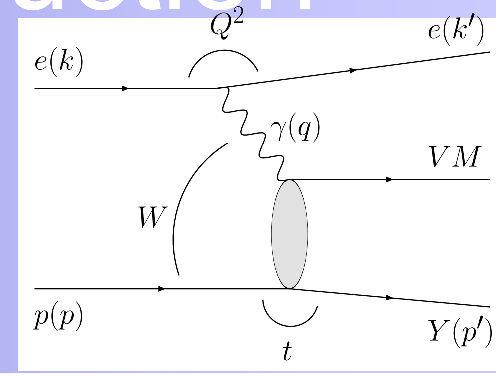
The distributions are similar in shape within the uncertainties.

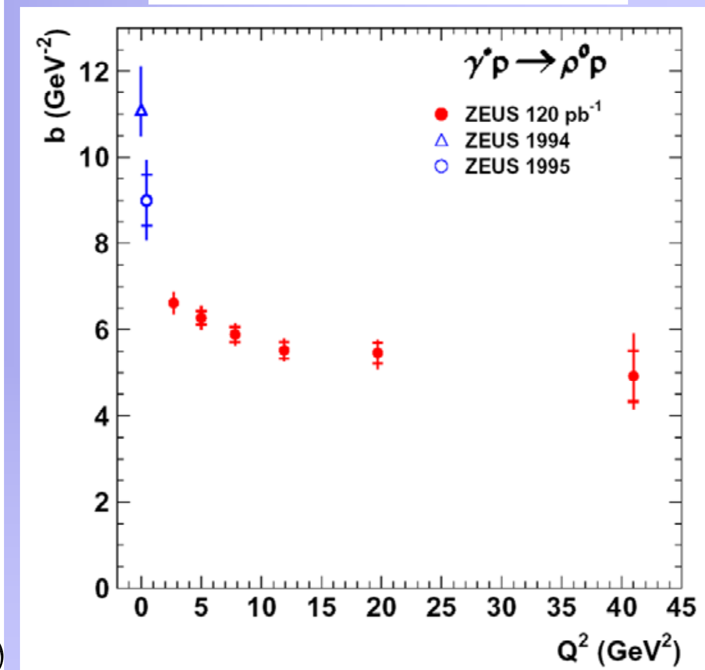
γp and γ^*p results

Vector meson production

(Pierre Marage, HERA-LHC 2008)





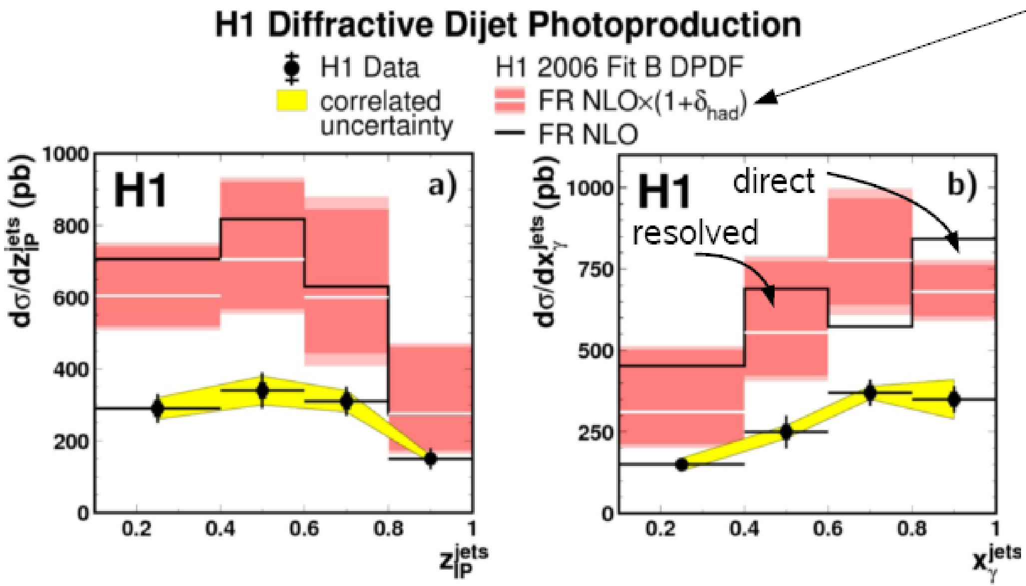


- *left* - why different σ vs. W slopes?
- *right* - why smaller b-slope in γ^*p?!

Dijets in γp at HERA - 2007

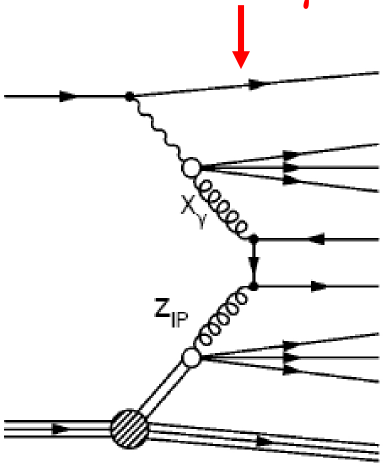
[slide from summary of the HERA/LHC Workshop of March 14, 2007]

Dijets in γp



Frixione NLO code
+ hadronizarion correction

Hadron-like γ



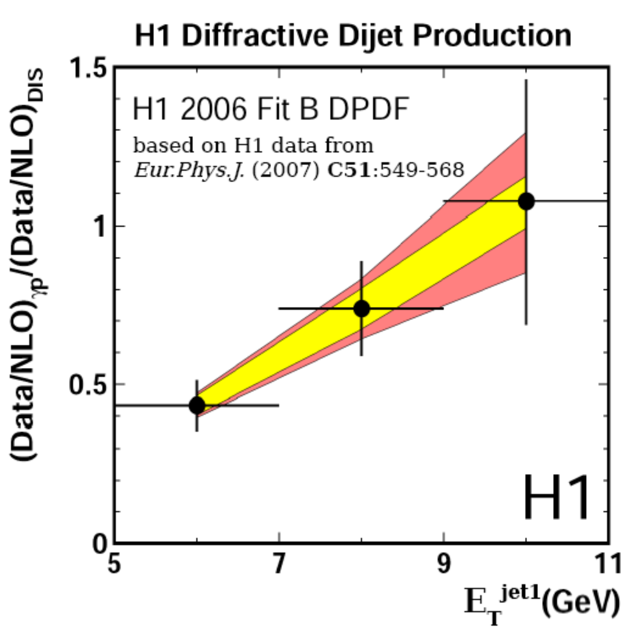
- large violation of naive factorization observed
- factorization breaking occurs in direct and resolved processes

QCD factorisation not OK

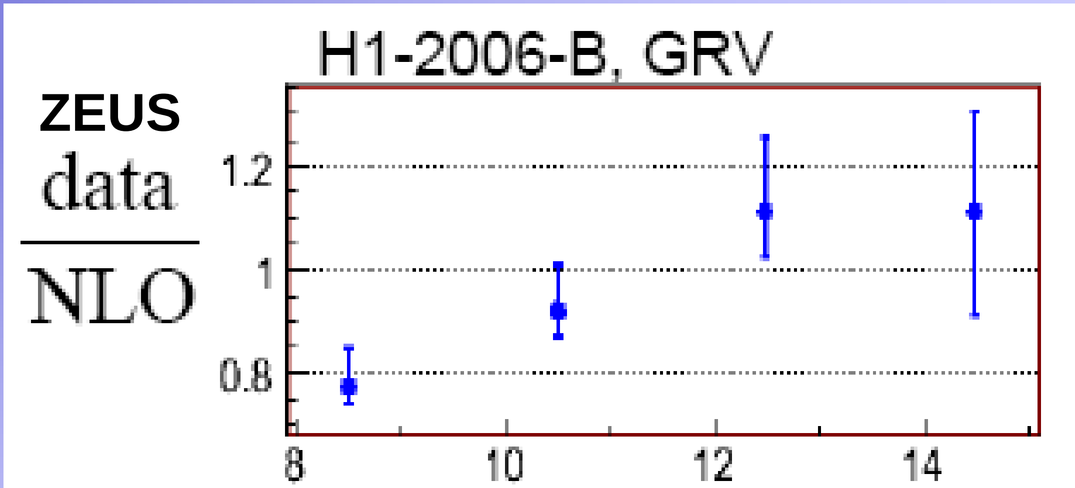
Unexpected, not understood

Matthias Mozer, HERA-LHC 2007 12

Dijets in γp at HERA - 2008



DIS 2008 talk by W. Slomiński,



- 20-50 % rise (?) from E^T 5→10 GeV

Renormalization: *the common thread*

➔ works for pp, $\bar{p}p$, γp and $\gamma^* p$

➔ removes overlapping gaps!

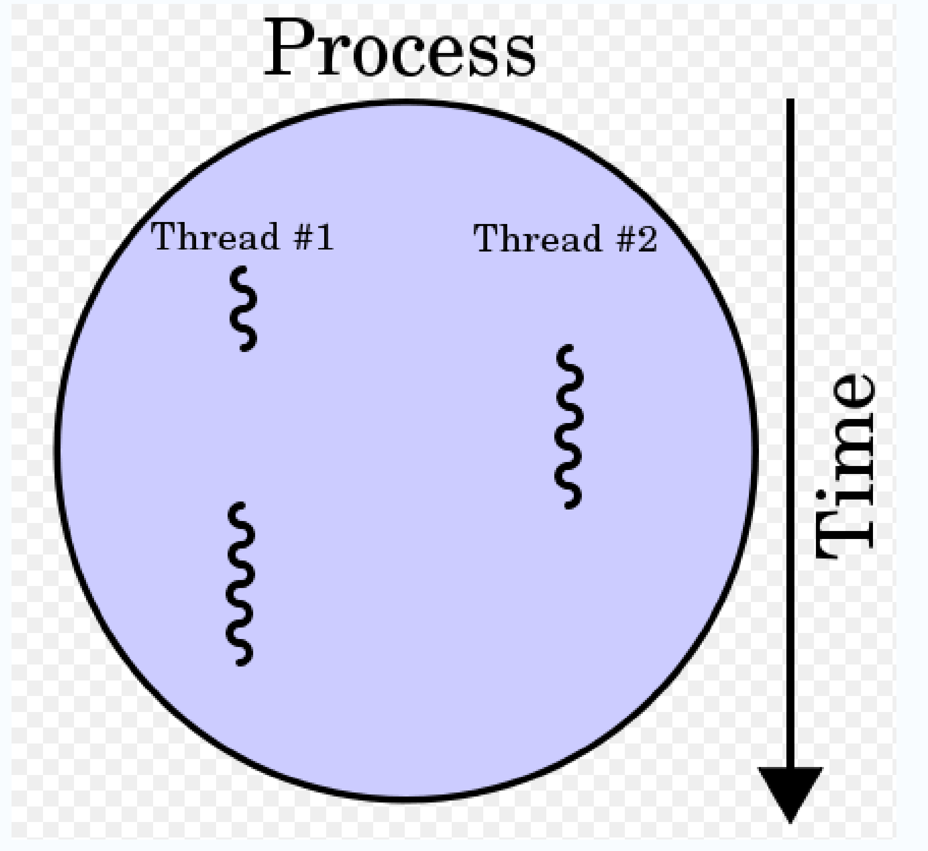
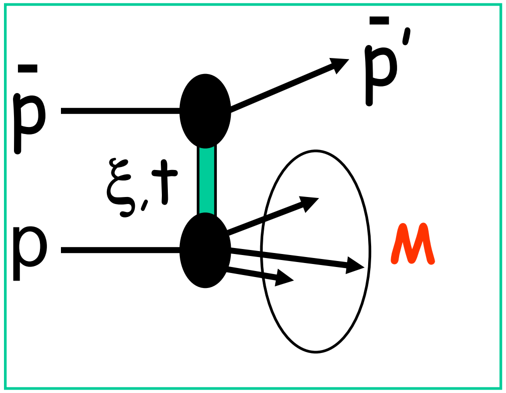
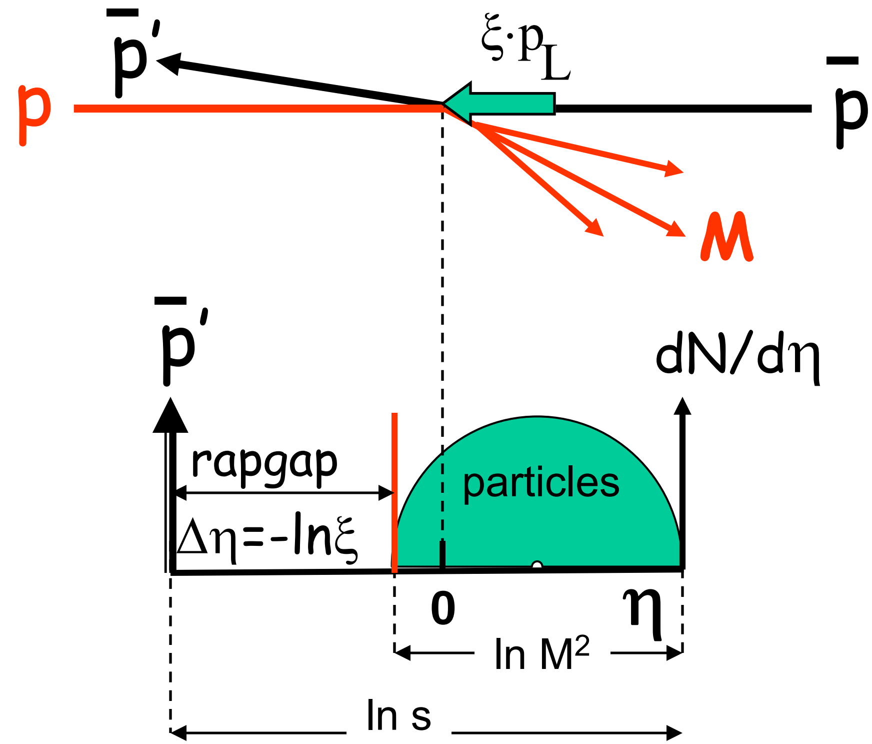


figure from http://en.wikipedia.org/wiki/Thread_(computer_science)

SD: M^2 scaling is expected in QCD



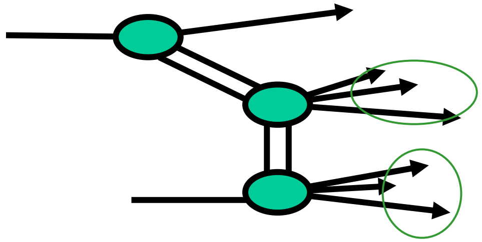


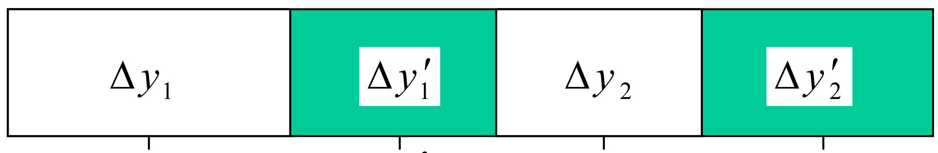
$$1 - x_L \equiv \xi = \frac{M^2}{s}$$

vacuum exchange ⇨

$$\left(\frac{d\sigma}{d\Delta\eta}\right)_{t=0} \approx \text{constant} \Rightarrow \frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \Rightarrow \frac{d\sigma}{dM^2} \propto \frac{1}{M^2}$$

Multigap Cross Sections





5 independent variables: y'_1, y_2, t_1, $\Delta y = \Delta y_1 + \Delta y_2$, t_2

color factor

$$\frac{d^5\sigma}{\prod_{i=1-5} dV_i} = C \times F_p^2(t_1) \prod_{\text{i=1-2}} \left\{ e^{(\varepsilon+\alpha' t_i)\Delta y_i} \right\}^2 \times \kappa^2 \left\{ \sigma_o \, e^{\varepsilon(\Delta y'_1 + \Delta y'_2)} \right\}$$

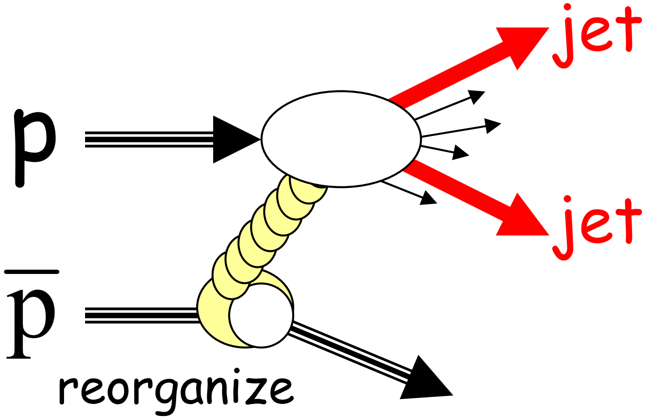
Gap probability

$$\int_{\Delta y, t} \sim s^{2\varepsilon} / \ln s$$

Sub-energy cross section (for regions with particles)

Same suppression as for single gap!

Diffractive dijets @ Tevatron



$$F^{D}(\xi, x, Q^2) \propto \frac{1}{\xi^{1+2\varepsilon}} \cdot F(x/\xi, Q^2)$$

$F^D_{JJ}(\xi,\beta,Q^2)$ @ Tevatron

$$F^D(\xi,\beta,Q^2) = \mathrm{N}_{\mathrm{renorm}}\frac{1}{\xi^{1+2\varepsilon}}\cdot\frac{C(Q^2)}{(x/\xi)^{\lambda(Q^2)}} = \frac{2\varepsilon}{(\beta\, s)^{2\varepsilon}}\cdot\frac{1}{\xi^{1+2\varepsilon}}\cdot\frac{C(Q^2)}{\beta^{\lambda(Q^2)}}$$

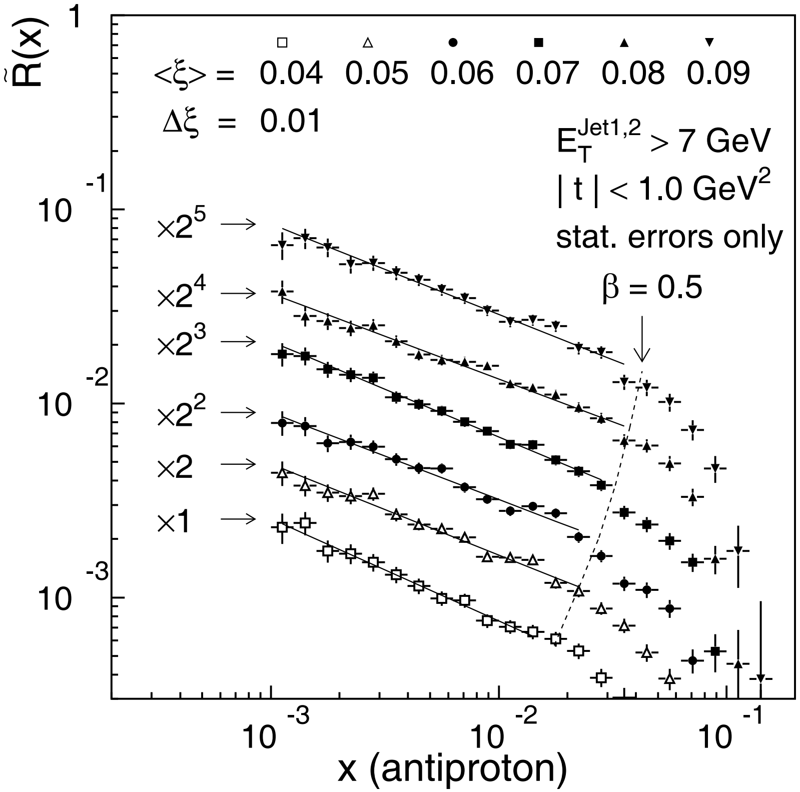
$$\mathrm{N}^{-1}_{\mathrm{renorm}} = \int_{\xi_{\min}}^{1}\frac{d\xi}{\xi^{1+2\varepsilon}} \xrightarrow{\xi_{\min}=\frac{x_{\min}}{\beta}\approx\frac{1}{\beta\, s}} \frac{(\beta\, s)^{2\varepsilon}}{2\varepsilon}$$

RENORM $\Rightarrow$ $R^{SD}_{ND}(x) = \frac{2\varepsilon}{s^{2\varepsilon}}\frac{1}{\xi^{1-\lambda(Q^2)}}\cdot x^{-(2\varepsilon)}$

$$\varepsilon_g = 0.2 \rightarrow x^{-0.4}$$

SD/ND dijet ratio vs. x_{Bj}@ CDF

CDF Run I



$$R(x) = \frac{F_{jj}^{SD}(x)}{F_{jj}^{ND}(x)}$$

0.035 < ξ < 0.095

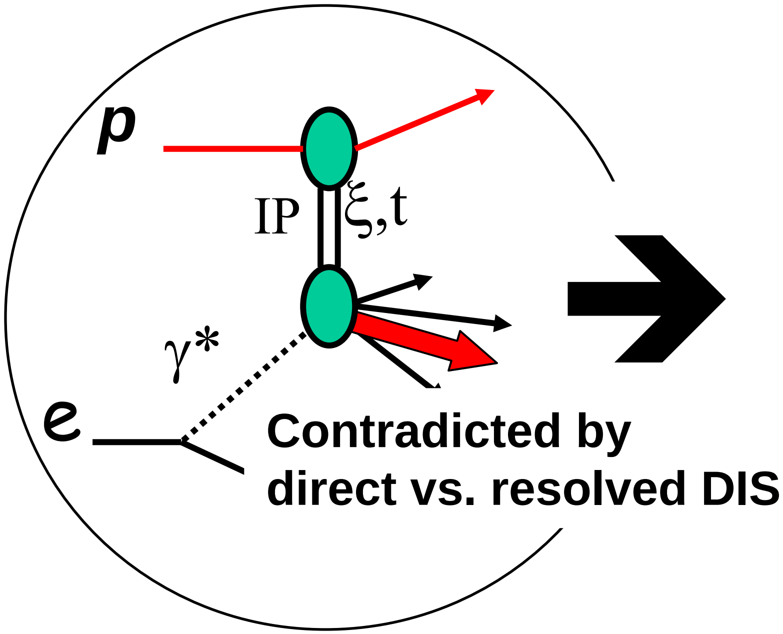
Flat ξ dependence for β < 0.5

$$R(x) = x^{-0.45}$$

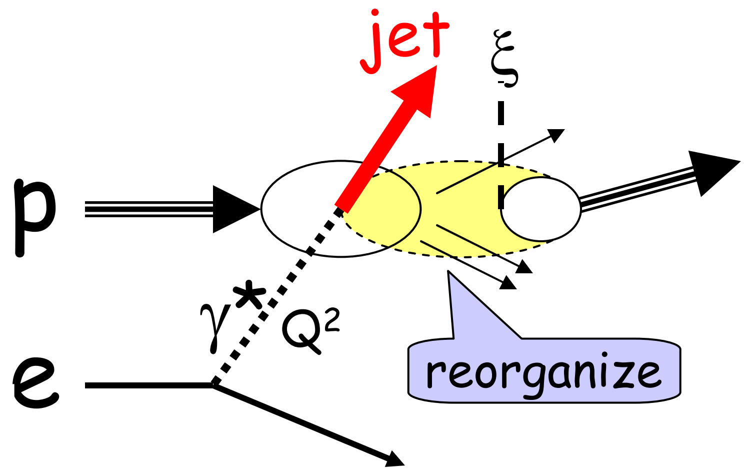
Diffractive DIS @ HERA

J. Collins: factorization holds (but under what contitions?)

Pomeron exchange



Color reorganization

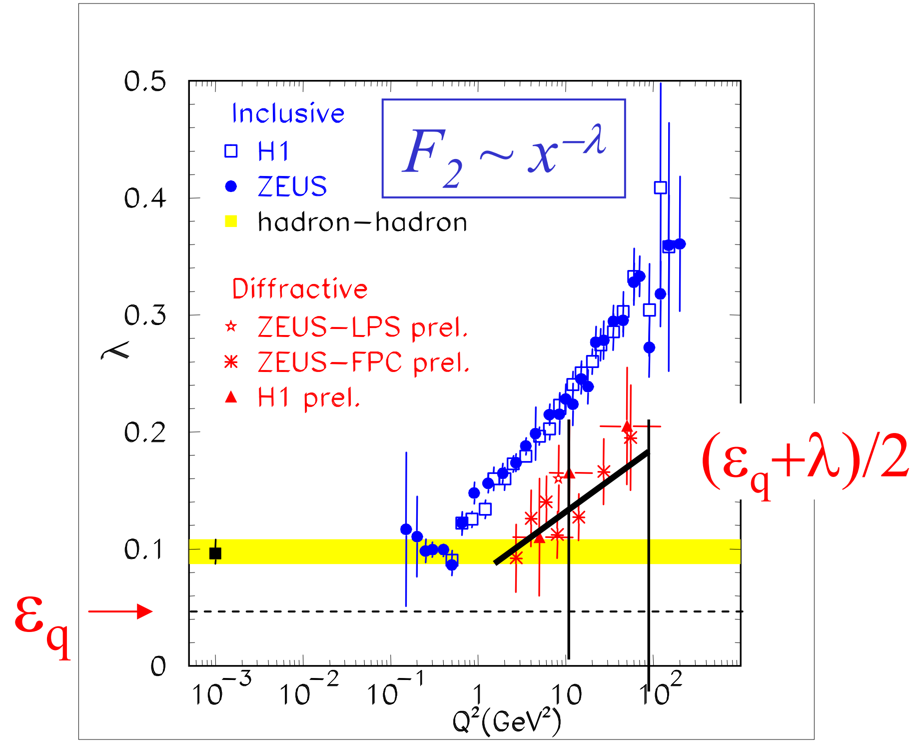


$$F_2^{D(3)}(\xi,x,Q^2) \propto \frac{1}{\xi^{1+\varepsilon}} \cdot F_2(x,Q^2)$$

$$F_2^{D(3)}(\xi,\beta,Q^2) \propto \frac{1}{\xi^{1+\varepsilon}} \cdot \frac{C(Q^2)}{(\beta\xi)^{\lambda(Q^2)}} \propto \frac{1}{\xi^{1+\varepsilon+\lambda(Q)^2}} \cdot \frac{C}{\beta^{\lambda}}$$

Inclusive vs. diffractive DIS

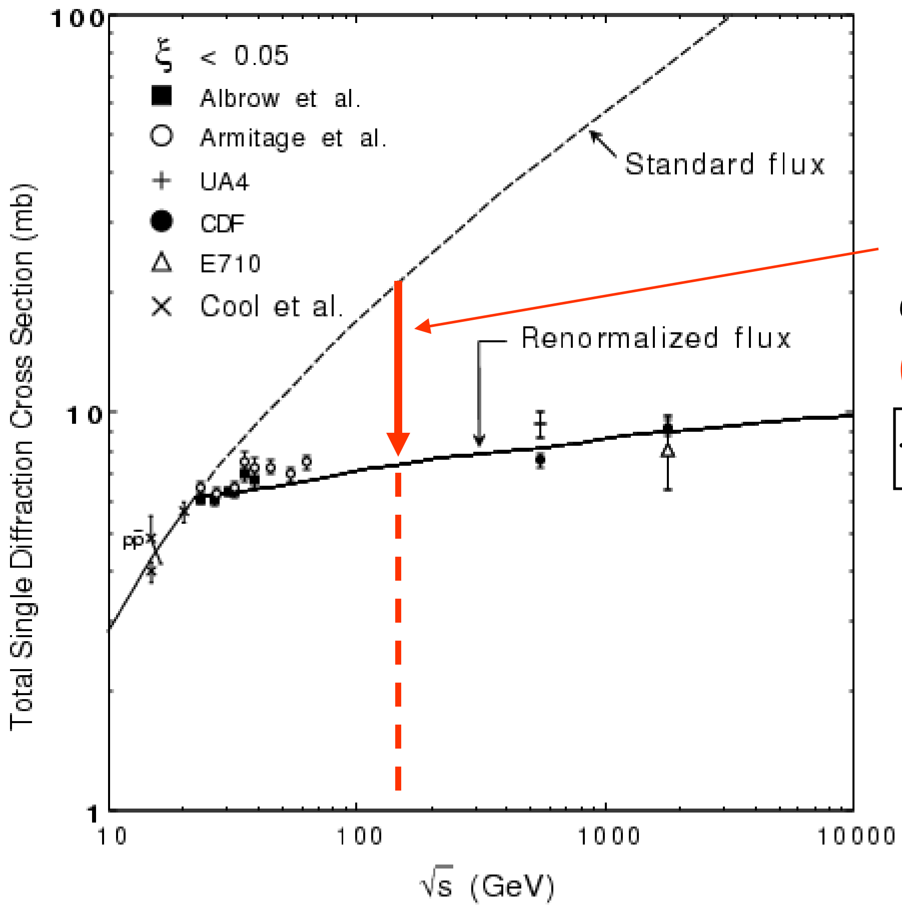
KG, "Diffraction: a New Approach," J.Phys.G26:716-720,2000 e-Print Archive: **hep-ph/0001092**



$$F_2^{D(3)}(\xi,\beta,Q^2) \propto \frac{1}{\xi^{1+\varepsilon}} \cdot \frac{C(Q^2)}{(\beta\xi)^{\lambda(Q^2)}} \propto \frac{1}{\xi^{1+\varepsilon+\lambda(Q)^2}} \cdot \frac{C}{\beta^{\lambda(Q^2)}}$$

Dijets in γp at HERA: the expectation

K. Goulianos, POS (DIFF2006) 055 (p. 8)

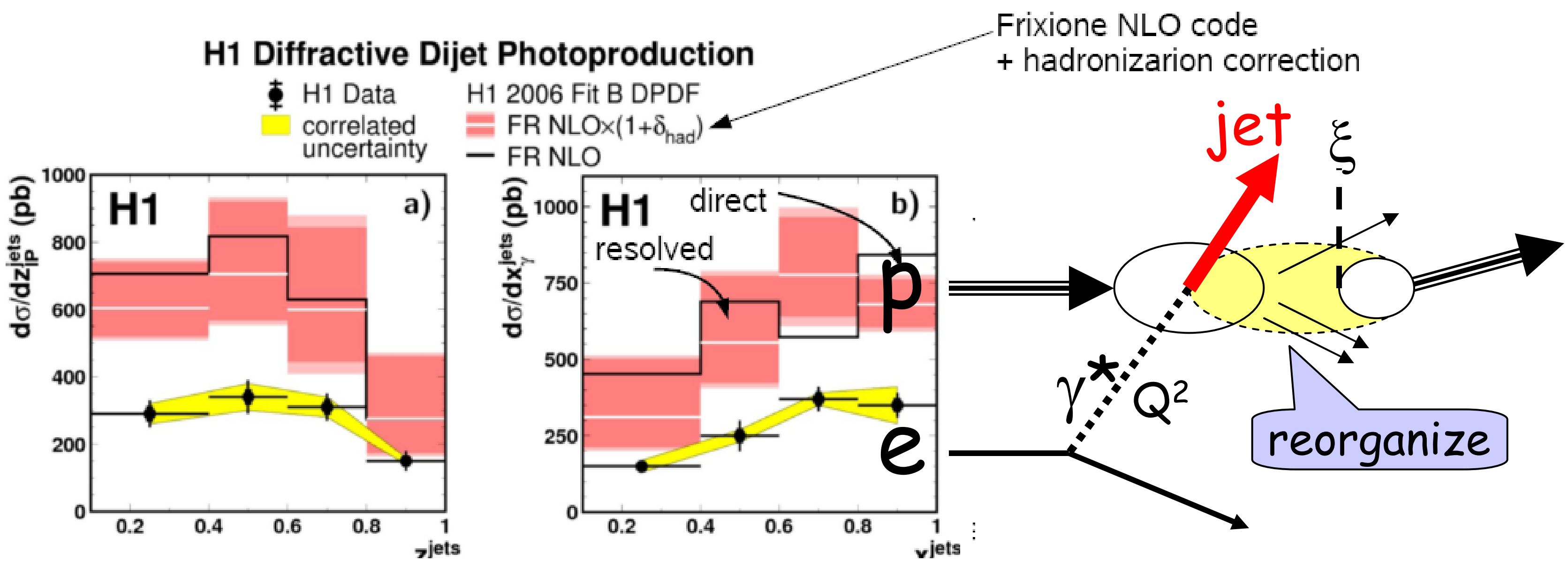


Factor of ~3 suppression
expected at W~200 GeV
(just as in pp collisions)

for both direct and resolved components

Dijets in γp at HERA - 2007

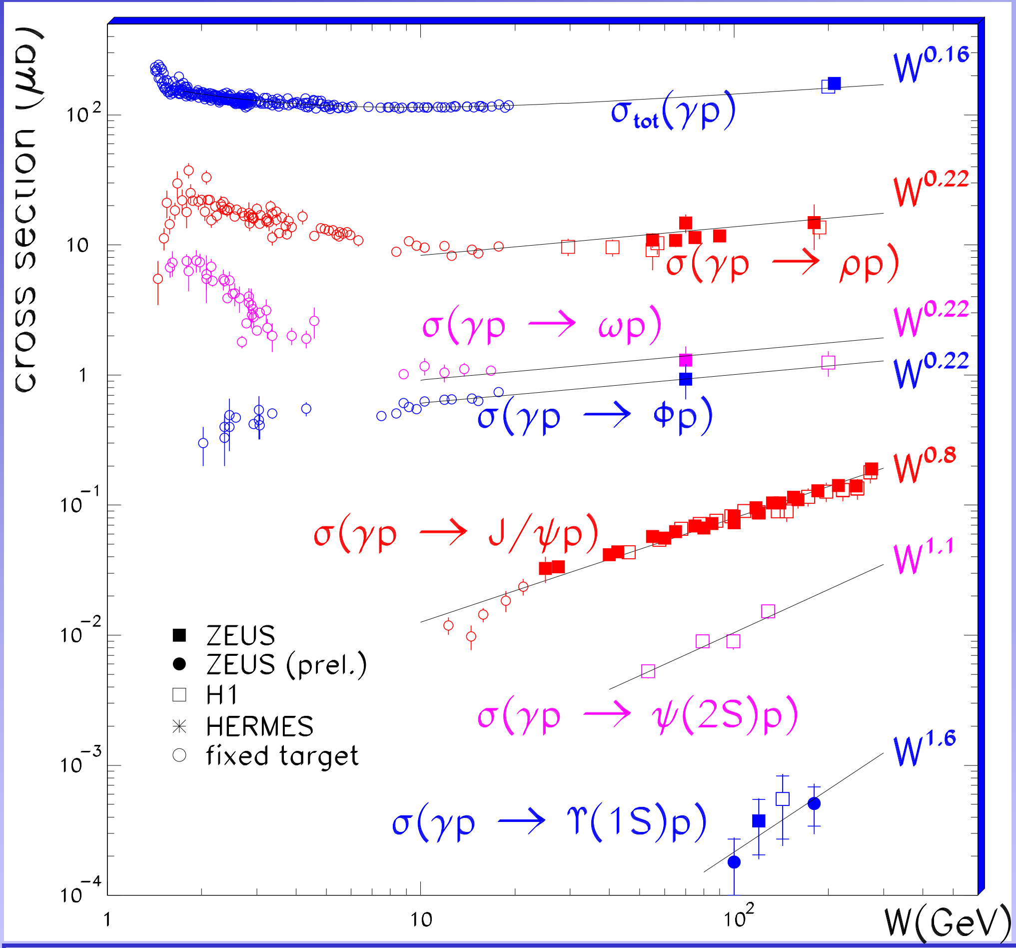
Dijets in γp

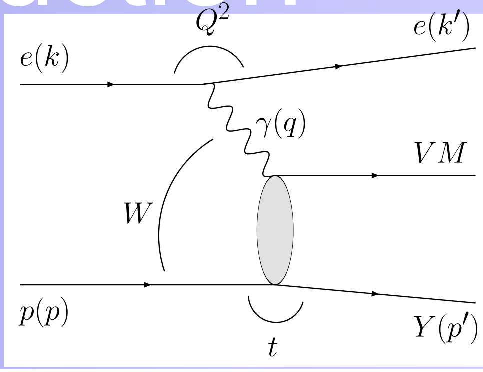


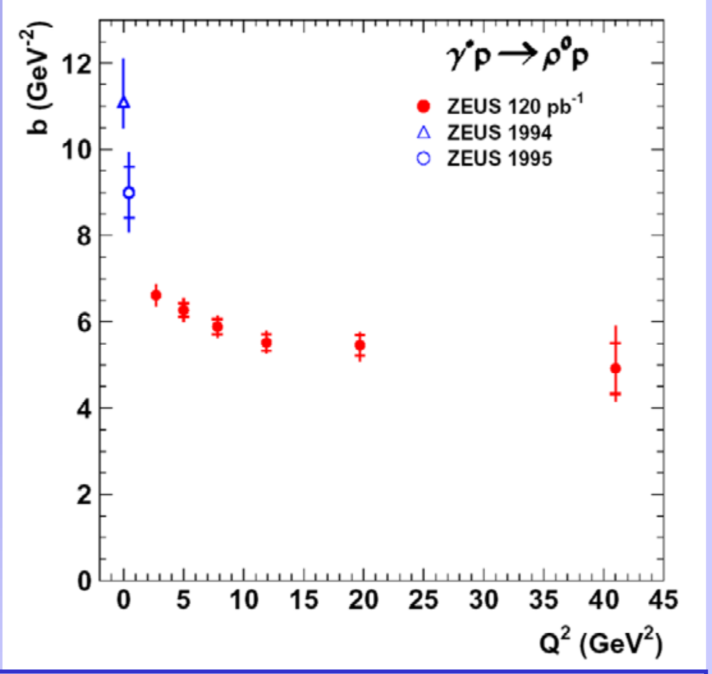
- ❑ see figure on right:
- ❑ ➔ same suppression for direct and resolved processes
- ❑ ➔ suppression at low v^{jets} since larger $\Delta\eta$ available for particles

Vector meson production

(Pierre Marage, HERA-LHC 2008)







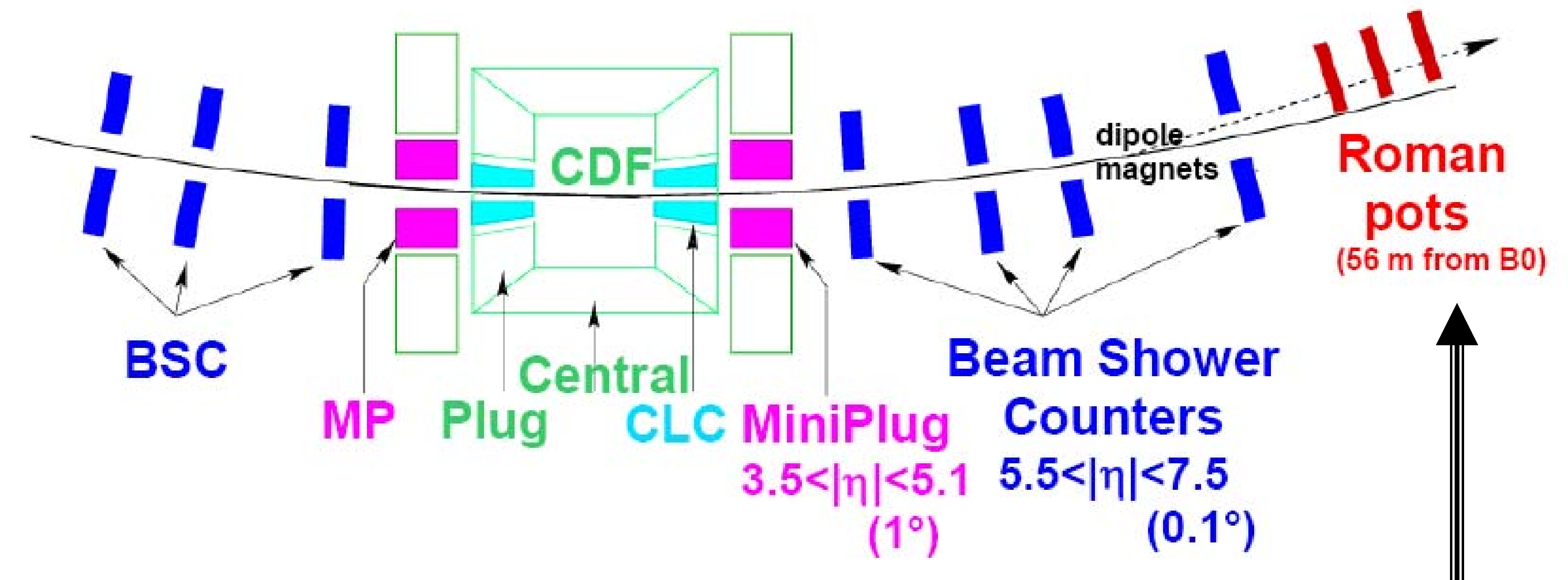
- *left* - suppression of 20-50 % at high W ➔ more room for particles
- *right* - suppression at low |t| for high Q^2 ➔ same reason


thank you
thank you

DISCUSSION

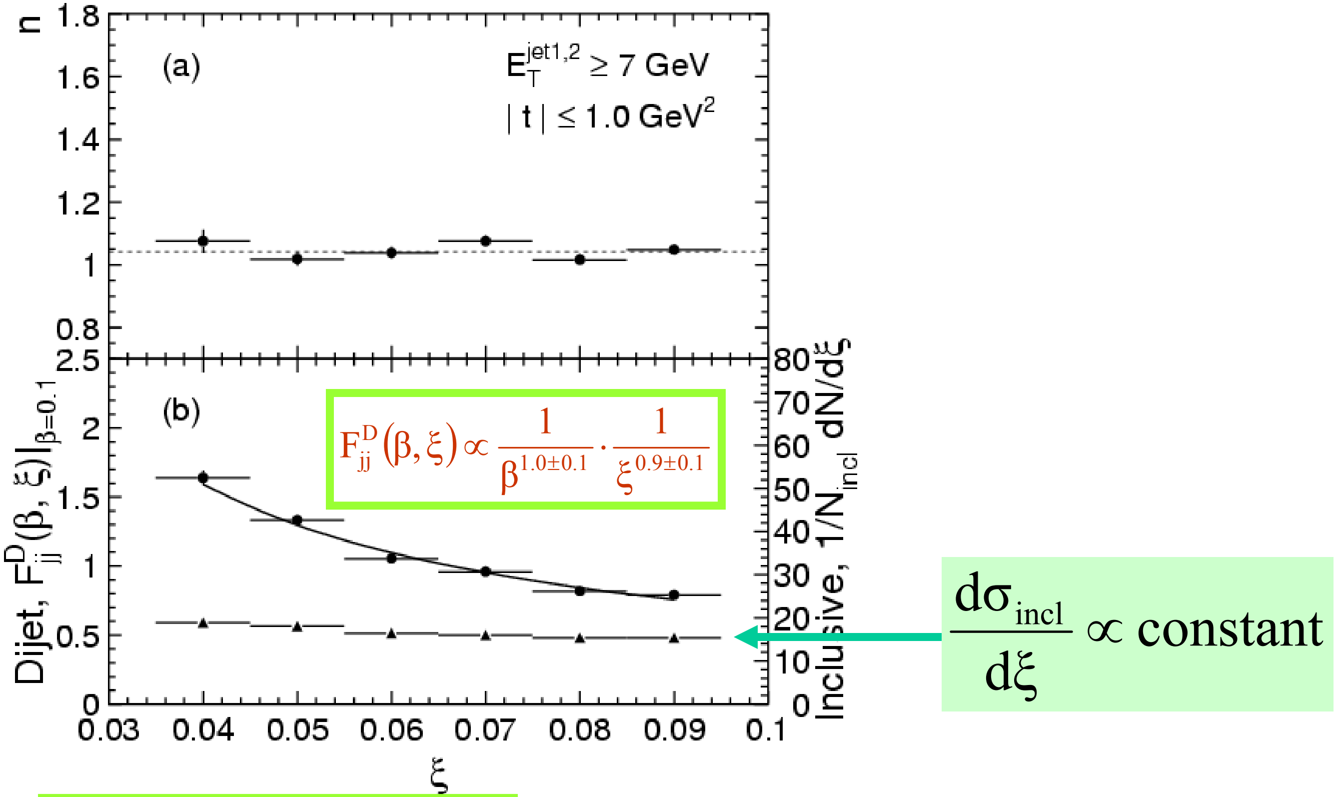
BACKUP

The CDF II detectors



RPS acceptance ~80% for $0.03 < \xi < 0.1$ and $|t| < 0.1$

ξ & β dependence of F^D_{jj} – Run I



$$F^D_{jj}(\beta,\xi) \sim \frac{1}{\beta} \cdot \frac{1}{\xi}$$

Pomeron dominated