Diffraction from CDF2LHC

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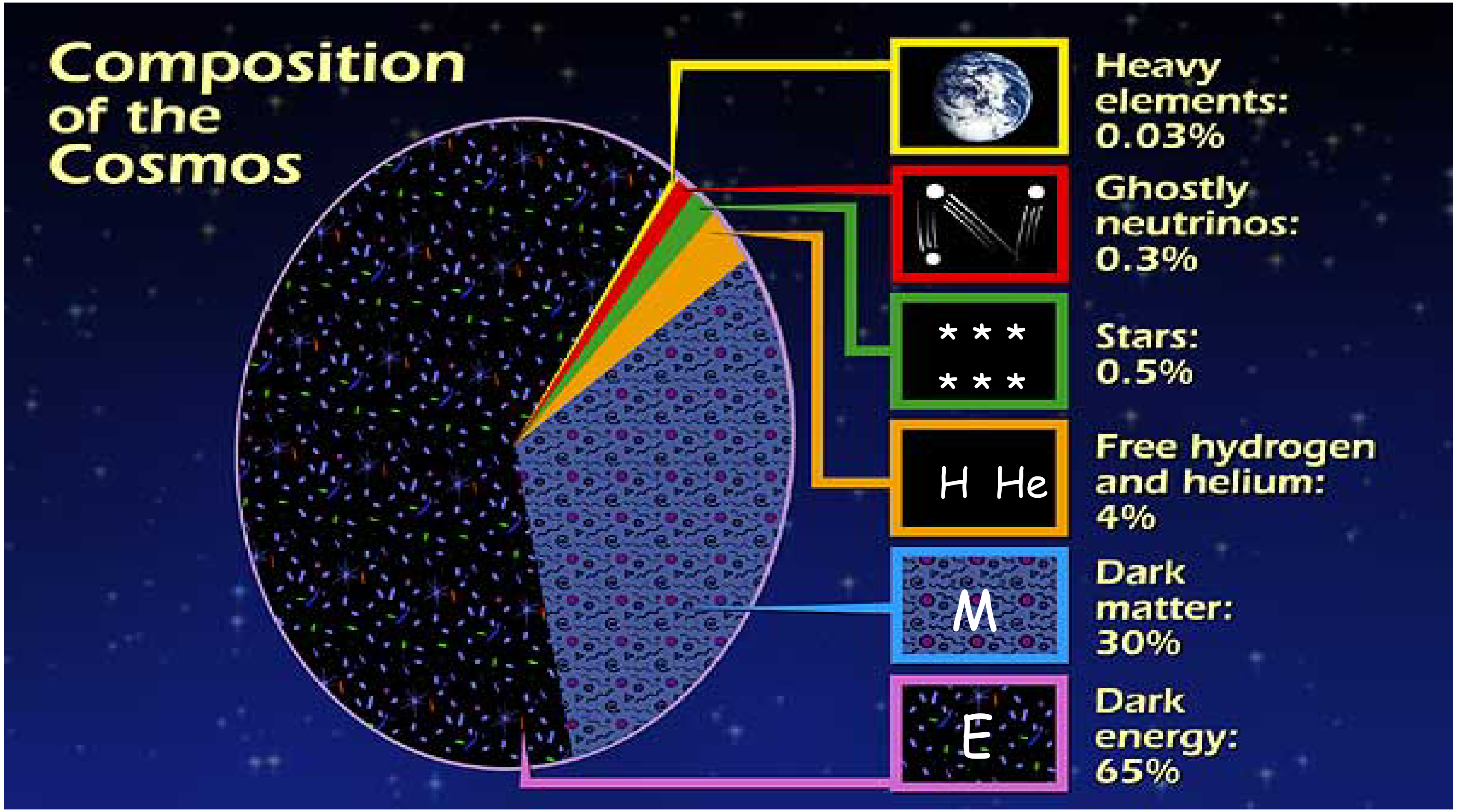
Tev4LHC
3-5 February 2005
Brookhaven National Laboratory

What is Dark Energy?



Rapidity Gaps

Bj, PRD 47 (1993) 101: regions of (pdeudo)rapidity devoid of particles

Non-diffractive interactions

Rapidity gaps are formed by multiplicity fluctuations.

From Poisson statistics:

$$P(\Delta y) = e^{-\rho \Delta y} \quad \left(\rho = \frac{dn}{dy} \right)$$

(ρ=particle density in rapidity space)

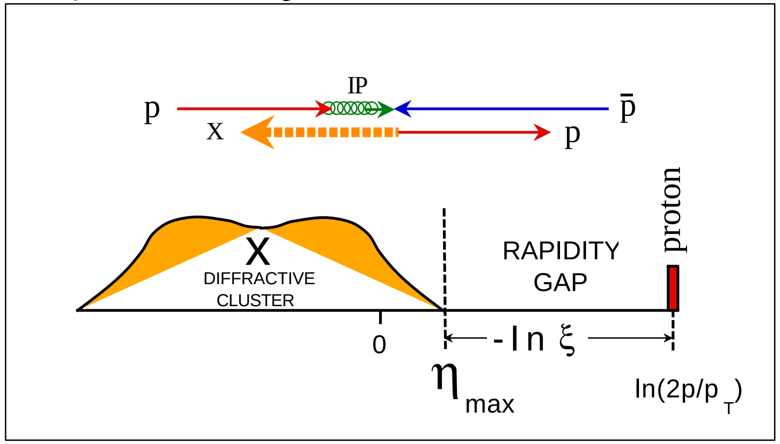
Gaps are exponentially suppressed

Diffractive interactions

Rapidity gaps at t=0 grow with Δy.

$$\xi \equiv \Delta p / p$$

$$\Delta y \approx -\ln \xi = \ln s - \ln M^2$$



$$\left(\frac{d\sigma}{d\Delta y} \right)_{t=0} \sim e^{2\varepsilon \Delta y} \Rightarrow \frac{d\sigma}{dM^2} \sim \frac{1}{(M^2)^{1+\varepsilon}}$$

2ε: negative particle density!

CDF Run I results

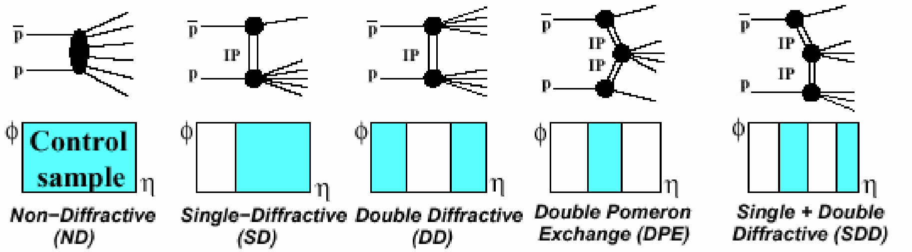
http://physics.rockefeller.edu/dino/my.html

Diffraction@CDF in Run I

16 papers

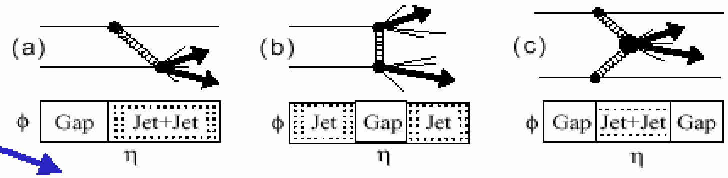
- Elastic scattering PRD 50 (1994) 5518
- Total cross section PRD 50 (1994) 5550
- Diffraction

SOFT diffraction



SD	DD	DPE	SDD
PRD 50 (1994) 5535	PRL 87 (2001)1418	PRL 93(2004)141601	PRL 91(2003)011802

HARD diffraction

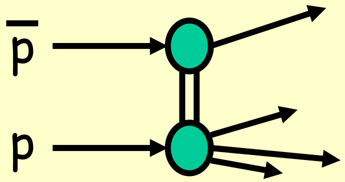


PRL references

W 78 (1997) 2698	JJ 74 (1995) 855	JJ 85 (2000) 4217
JJ 79 (1997) 2636	JJ 80 (1998) 1156	
b-quark 84 (2000) 232	JJ 81 (1998) 5278	
J/ψ 87 (2001) 241802		

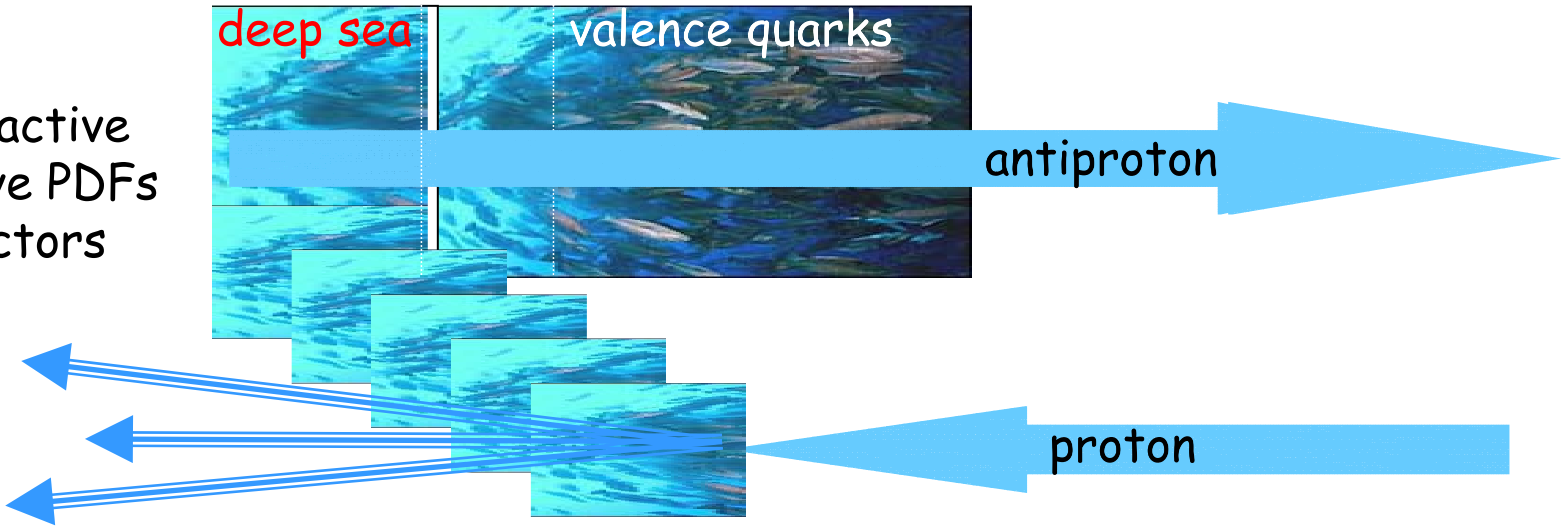
with roman pots

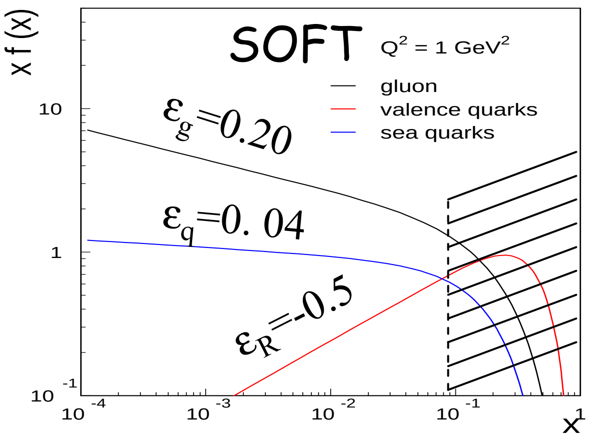
JJ	84 (2000) 5043
JJ	88 (2002) 151802



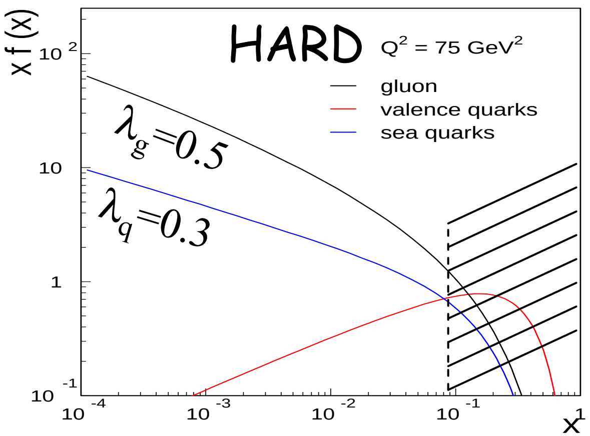
Single Diffraction

Derive diffractive from inclusive PDFs and color factors

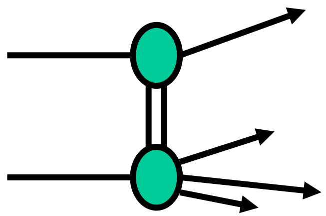




$$x \cdot f(x) = \frac{1}{x^{\varepsilon\,(\mathrm{or}\ \lambda)}}$$



Inclusive Single Diffraction



$$\frac{d^2\sigma_{SD}}{dt\,d\xi} = f_{IP/p}(t,\xi) \bullet \sigma_{IP-\bar{p}}(M_X^2)$$

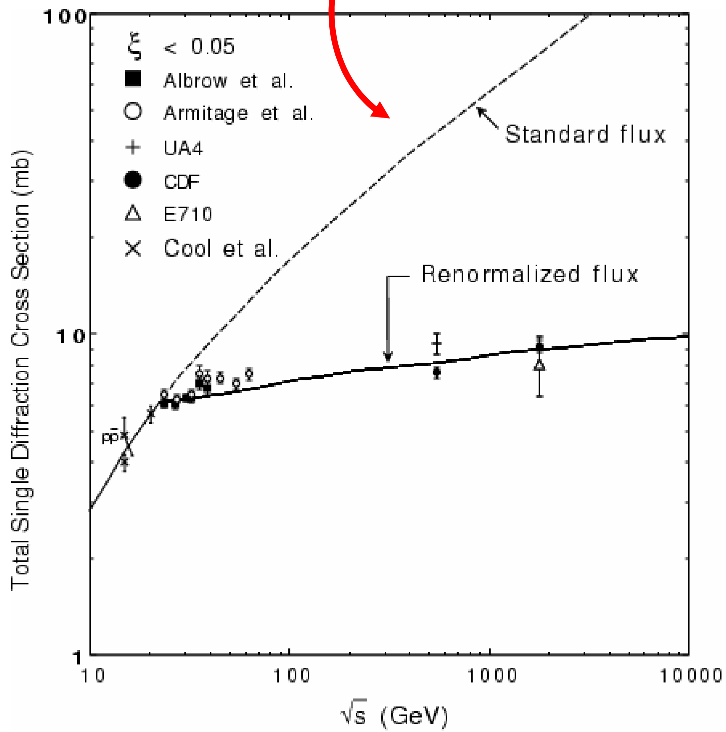
$$\sigma_{SD} \sim s^{2\varepsilon}$$

- **Unitarity problem:**
  Using factorization
  and std pomeron flux
  σ_{SD} exceeds σ_T at $\sqrt{s} \approx 2$ TeV.

- **Renormalization:**
  normalize the Pomeron
  flux to unity

KG, PLB 358 (1995) 379

$$\int_{\xi_{min}}^{0.1} \int_{t=-\infty}^{0} f_{IP/p}(t,\xi)\, d\xi\, dt = 1$$



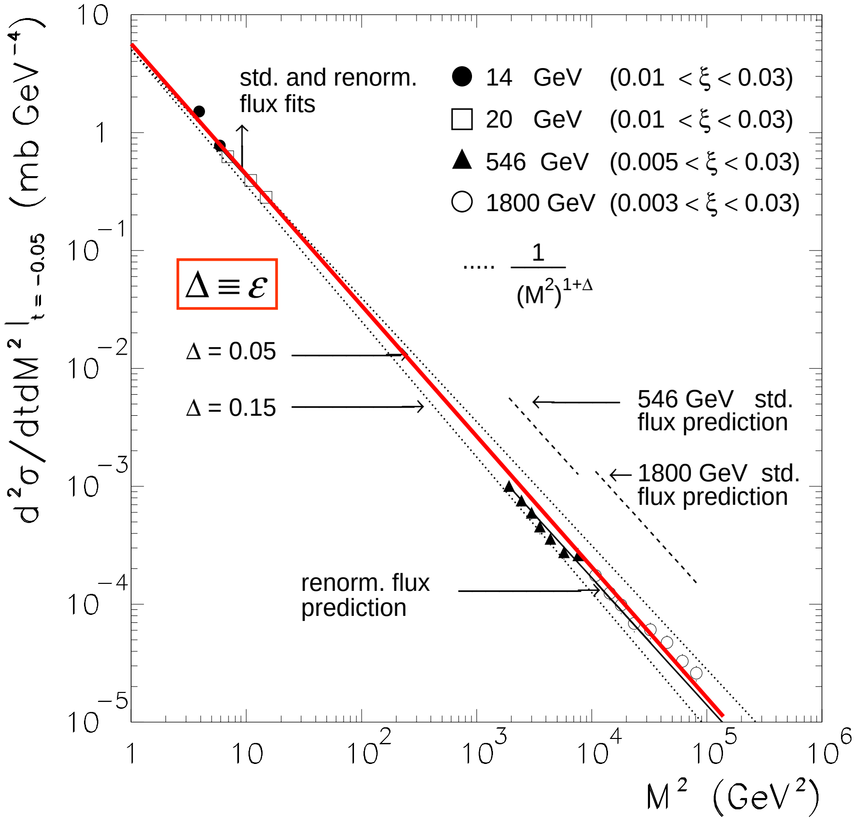
A Scaling Law in Diffraction

Factorization breaks down in favor of M^2-scaling

renormalization

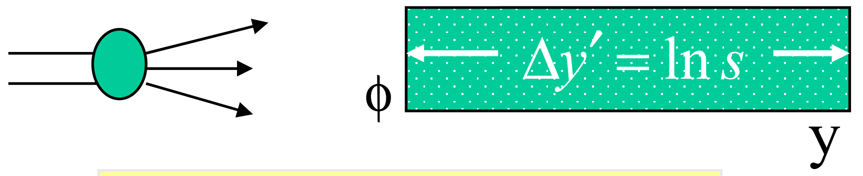
$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\varepsilon} \rightarrow 1}{(M^2)^{1+\varepsilon}}$$

KG&JM, PRD 59 (1999) 114017



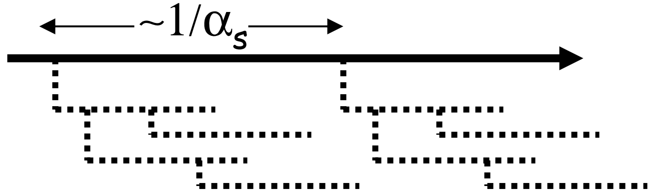
Elastic and Total Cross Sections

QCD expectations



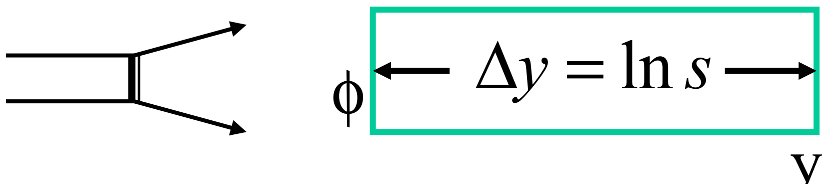
$$\sigma_T(s) = \sigma_o\, s^{\varepsilon} = \sigma_o\, e^{\varepsilon \Delta y'}$$

Total cross section:
power law rise with energy



The exponential rise of $\sigma_T(\Delta y')$ is due to the increase of wee partons with $\Delta y'$

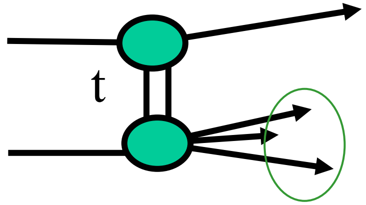
(see E. Levin, An Introduction to Pomerons,Preprint DESY 98-120)

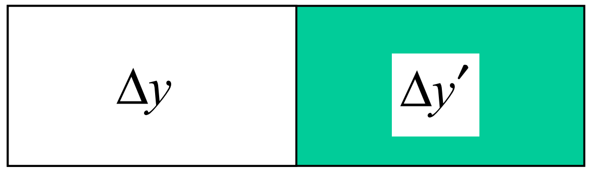


$$\mathrm{Im}\, f_{el}(s,t) \propto e^{(\varepsilon+\alpha' t)\Delta y}$$

Elastic cross section:
forward scattering amplitude

Soft Diffraction
(KG, hep-ph/0205141)





2 independent variables: $t, \Delta y$

color factor: $\kappa = \dfrac{g_{IP-IP-IP}(t)}{\beta_{IP-p-p}(0)} \approx 0.17$

$$\frac{d^2\sigma}{dt\, d\Delta y} = \underbrace{C \bullet F_p^2(t) \bullet \left\{e^{(\varepsilon+\alpha' t)\Delta y}\right\}^2}_{\text{gap probability}} \bullet \kappa \bullet \underbrace{\left\{\sigma_o\, e^{\varepsilon\, \Delta y'}\right\}}_{\text{sub-energy x-section}}$$

gap probability $\downarrow$ $\sim e^{2\varepsilon \Delta y}$ $\longrightarrow$

$$\int_{\Delta y_{\min}}^{\Delta y = \ln s} s^{2\varepsilon\, \Delta y}\, d\Delta y \approx s^{2\varepsilon}$$

Renormalization removes the s-dependence → SCALING

The Factors κ and ε

Experimentally:

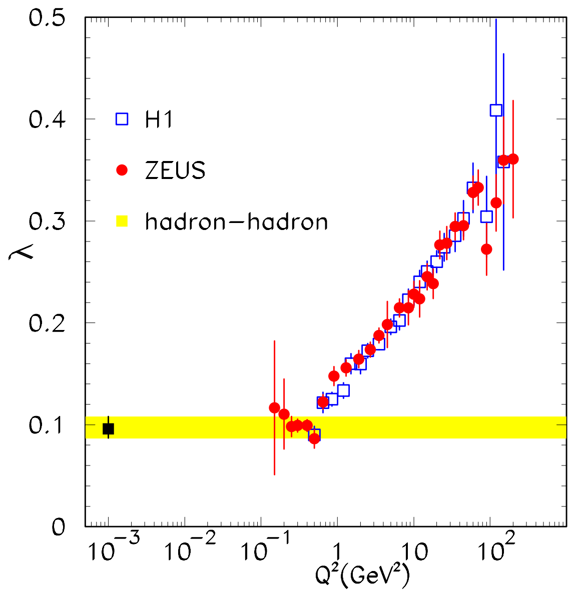
$$\kappa = \frac{g_{IP-IP-IP}}{\beta_{IP-p}} = 0.17 \pm 0.02, \quad \varepsilon = 0.104$$

KG&JM, PRD 59 (114017) 1999

Color factor: $\kappa = f_g \times \frac{1}{N_c^2 - 1} + f_q \times \frac{1}{N_c} \xrightarrow{Q^2 = 1} \approx 0.75 \times \frac{1}{8} + 0.25 \times \frac{1}{3} = 0.18$

Pomeron intercept: $\varepsilon = \lambda_g \cdot w_g + \lambda_q \cdot w_q = 0.12$

λ HERA

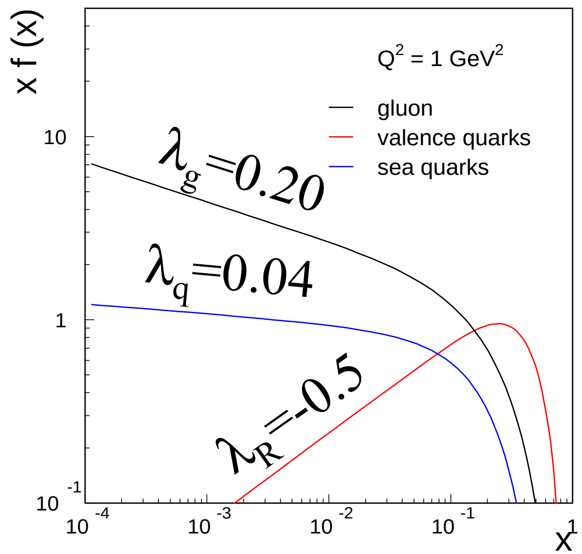


$$x \cdot f(x) = \frac{1}{x^{\lambda}}$$

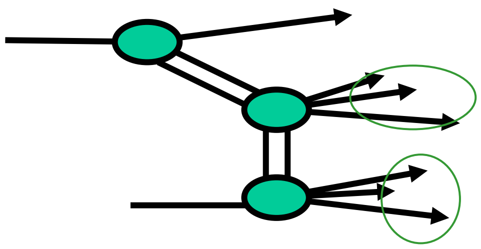
f_g=gluon fraction
f_q=quark fraction

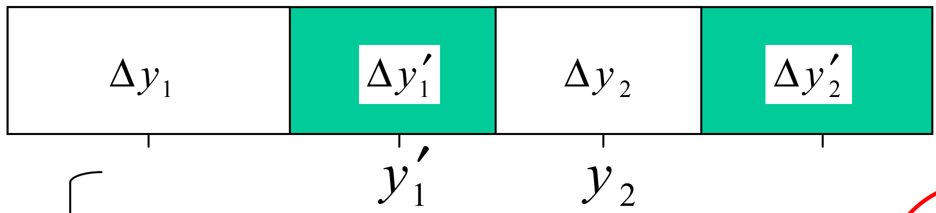
$$\int_{x=1/s}^{1} f(x)\,dx \sim s^{\lambda}$$

CTEQ5L



Multigap Diffraction
(KG, hep-ph/0205141)





5 independent variables $\left\{ t_1 \quad \Delta y = \Delta y_1 + \Delta y_2 \quad t_2 \right.$

color factors

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

Gap probability

$\sim e^{2\varepsilon \Delta y}$

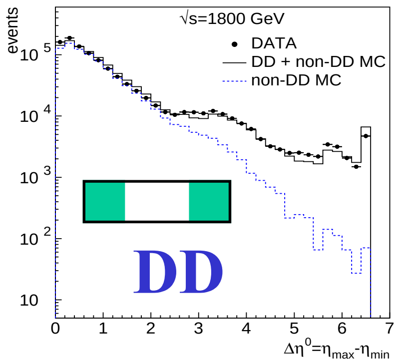
Sub-energy cross section (for regions with particles)

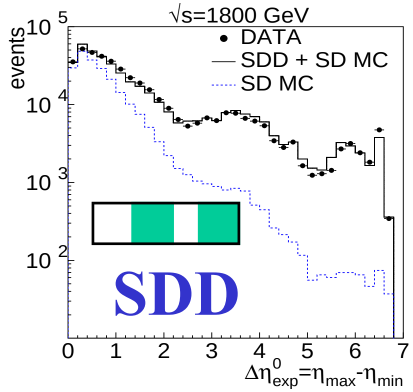
$$\int_{\Delta y_{\min}}^{\Delta y = \ln s} s^{2\varepsilon\,\Delta y} \approx s^{2\varepsilon}$$

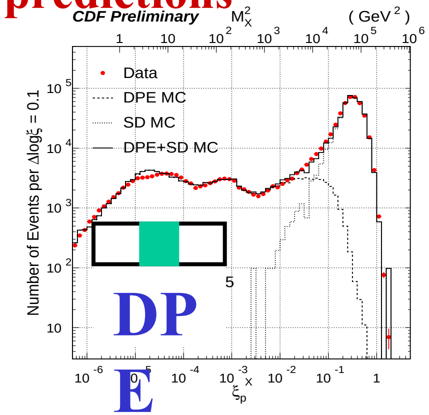
Same suppression as for single gap!

Central and Two-Gap CDF Results

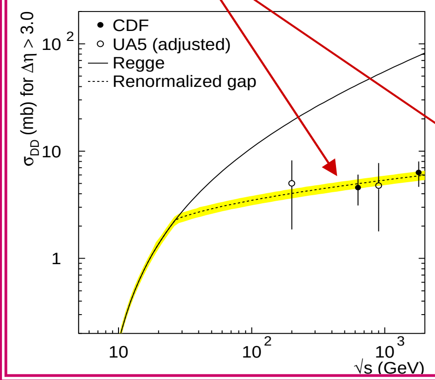
Differential shapes agree with Regge predictions

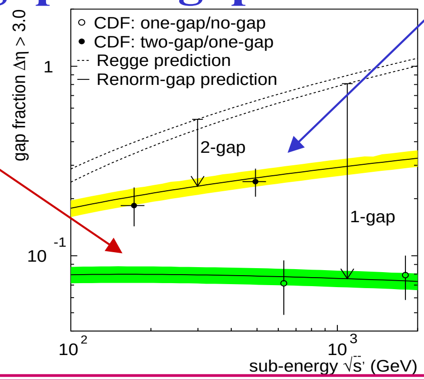


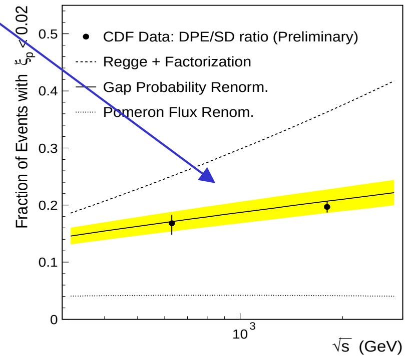




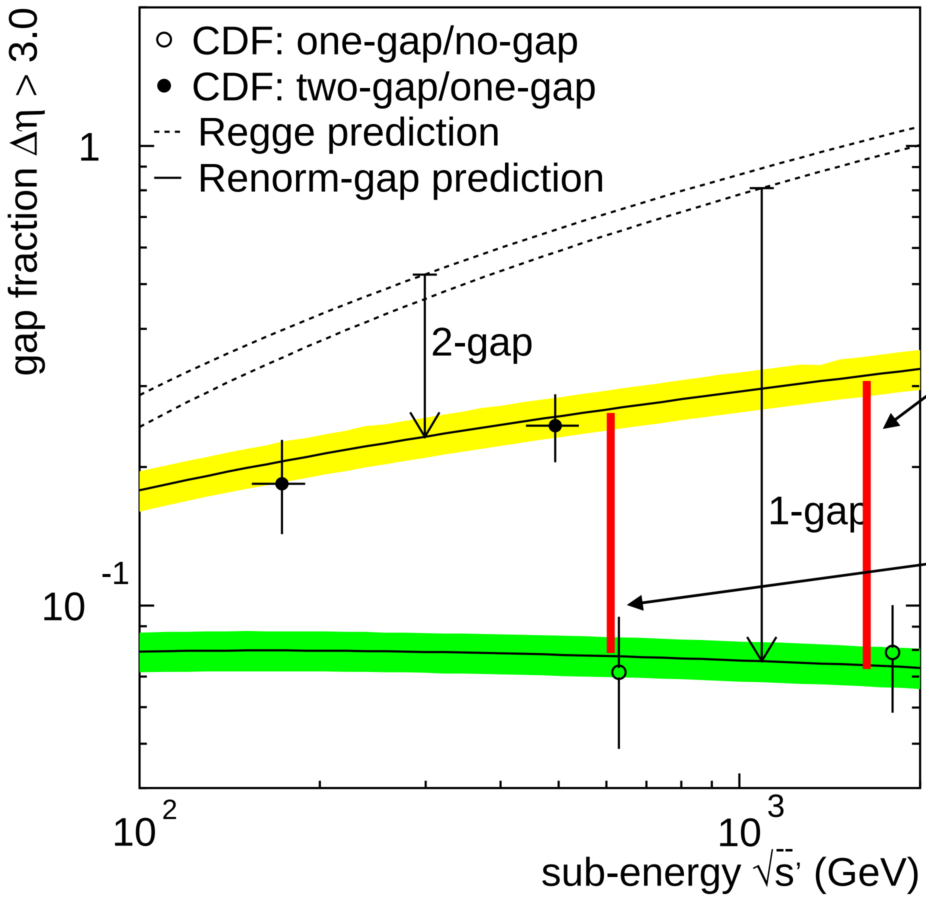
- **One-gap cross sections are suppressed**
- **Two-gap/one-gap ratios are** $\approx \kappa = 0.17$

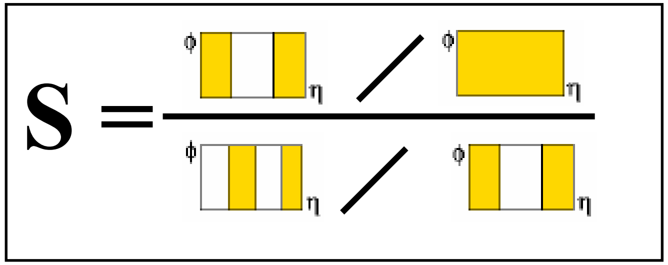






Gap Survival Probability





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

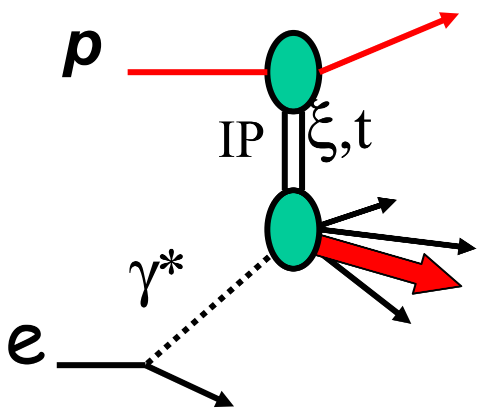
$$S^{1-gap/0-gap}_{2-gap/1-gap}(630\ GeV) \approx 0.29$$

Results similar to predictions by:
Gotsman-Levin-Maor
Kaidalov-Khoze-Martin-Ryskin
Soft color interactions

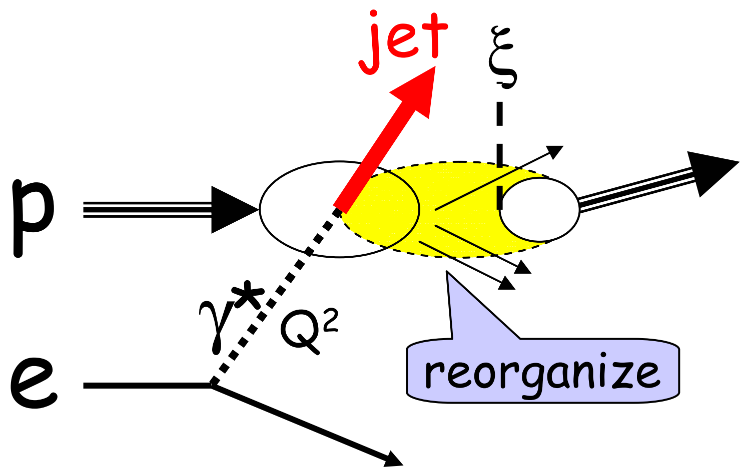
Diffractive DIS @ HERA

Factorization holds: J. Collins

Pomeron exchange



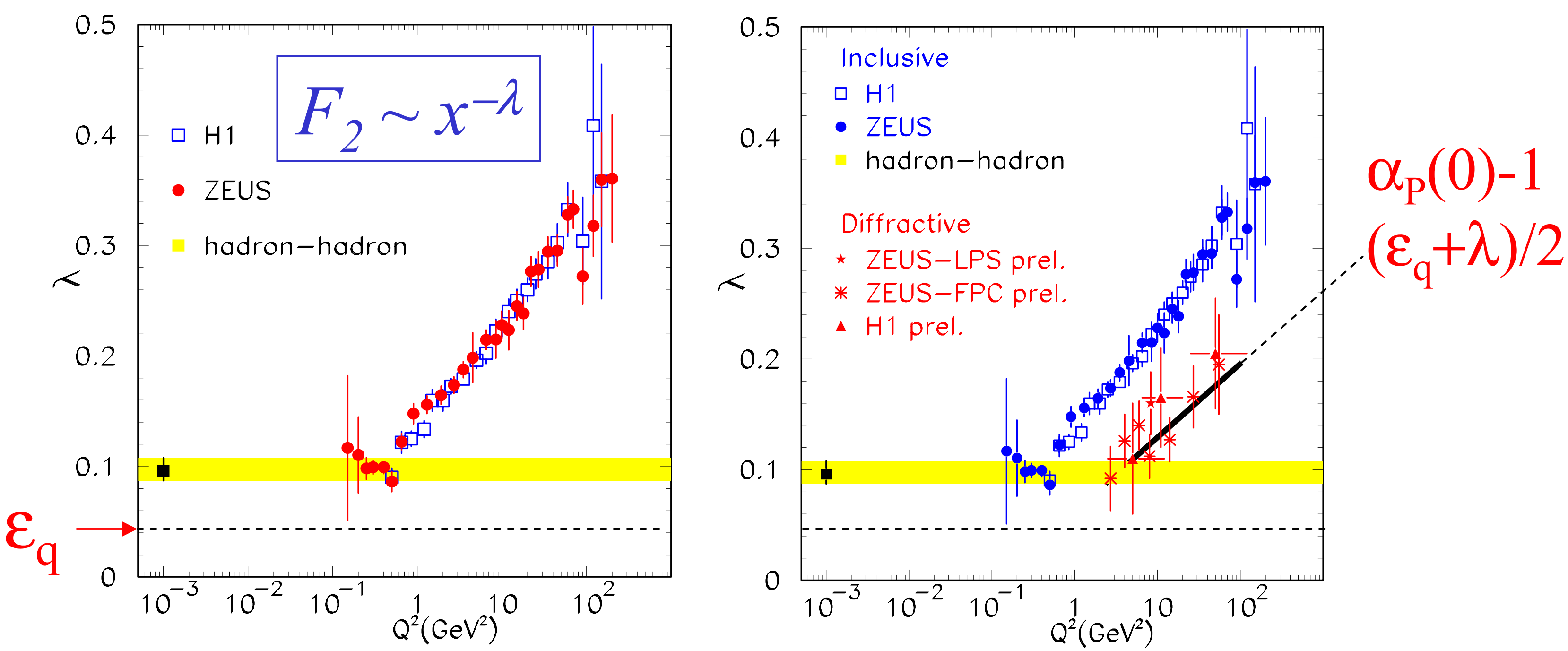
Color reorganization



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

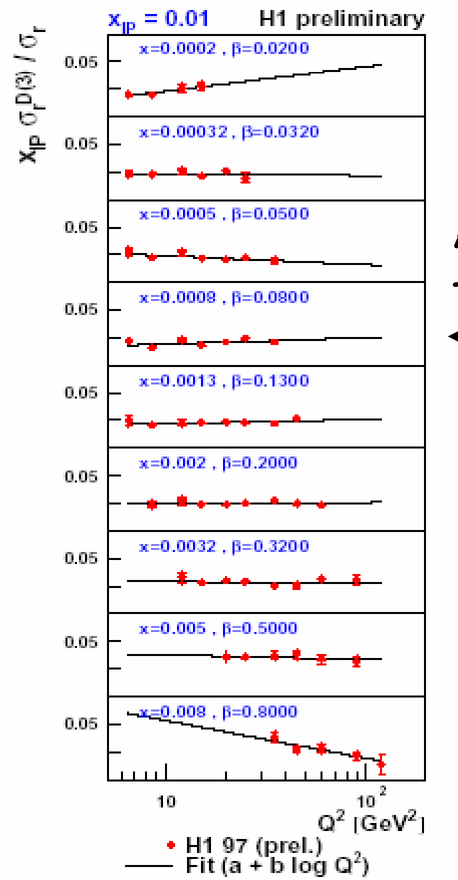
Inclusive vs Diffractive DIS

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



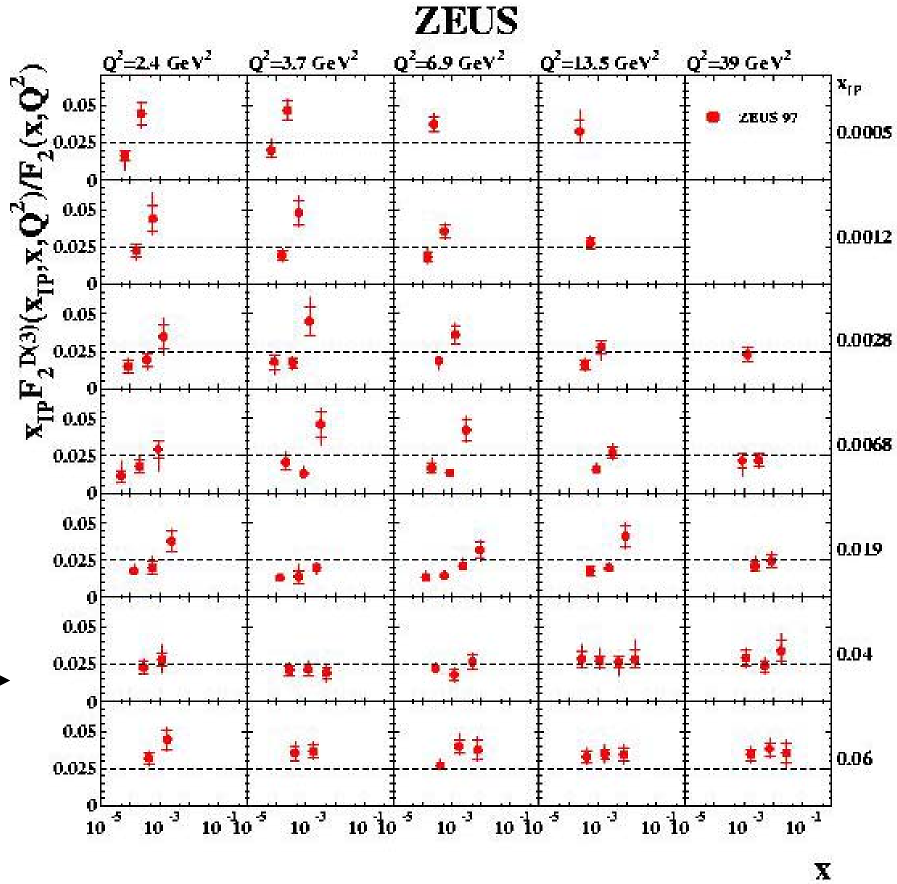
$$F_2^{D(3)}(\xi,\beta,Q^2) \propto \frac{1}{\xi^{1+\varepsilon}} \cdot \frac{C(Q^2)}{(\beta\xi)^{\lambda(Q^2)}} \propto \frac{1}{\xi^{1+\varepsilon+\lambda}} \cdot \frac{C}{\beta^{\lambda}}$$

$\sigma^{diff}/\sigma^{incl}$ DIS at HERA

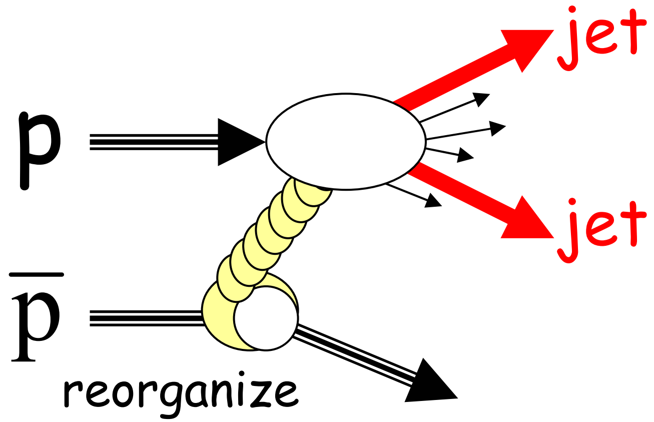


At fixed x:
flat Q^2-dependence

At fixed Q^2:
flat x-dependence



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

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

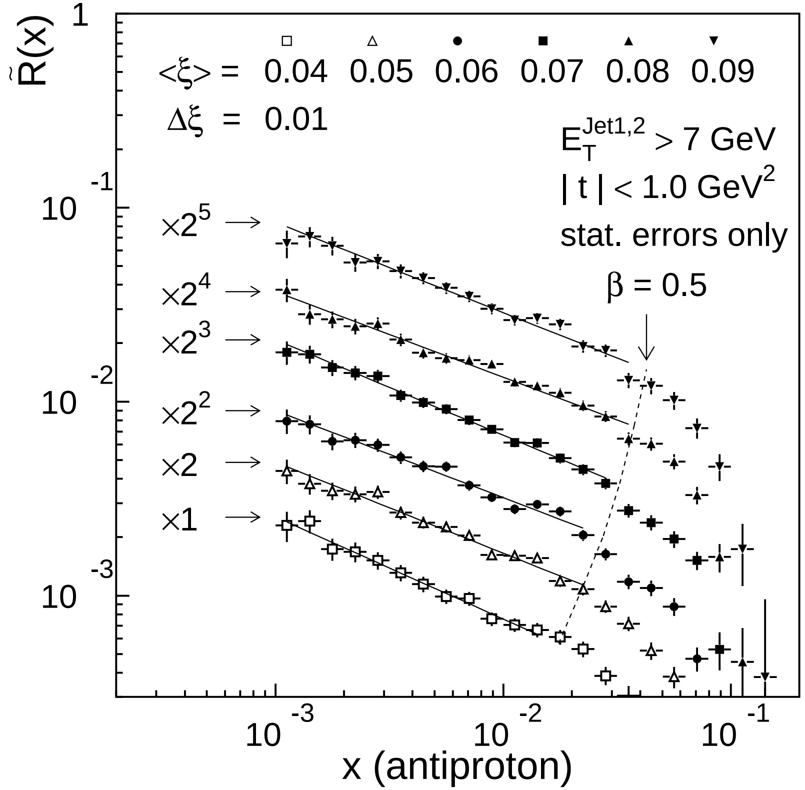
$$N^{-1}_{\text{renorm}} = \int_{\xi_{\min}}^{1} \frac{d\xi}{\xi^{1+2\varepsilon}} \xrightarrow{\xi_{\min} = \frac{x_{\min}}{\beta} \sim \frac{1}{\beta\, s}} (\beta\, s)^{2\varepsilon}$$

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

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

SD/ND Dijet Ratio vs x_{Bj}@ CDF

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



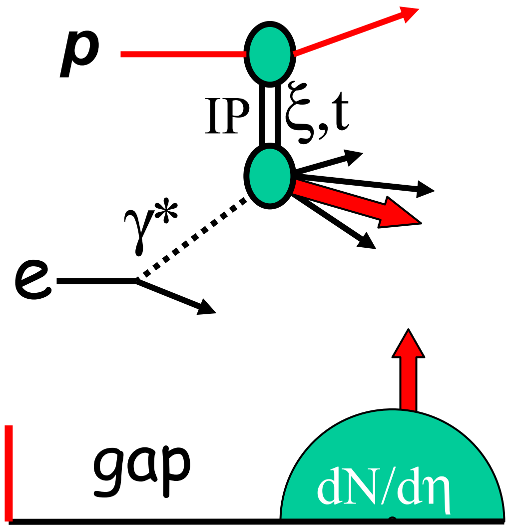
0.035 < ξ < 0.095

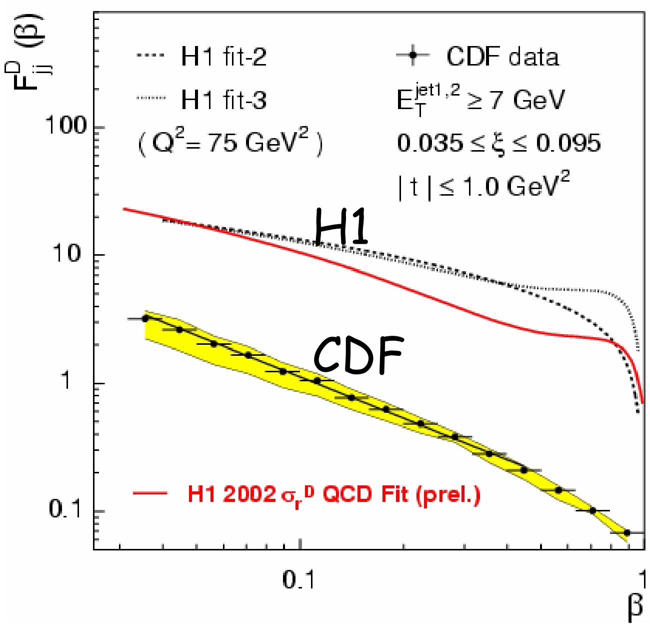
Flat ξ dependence

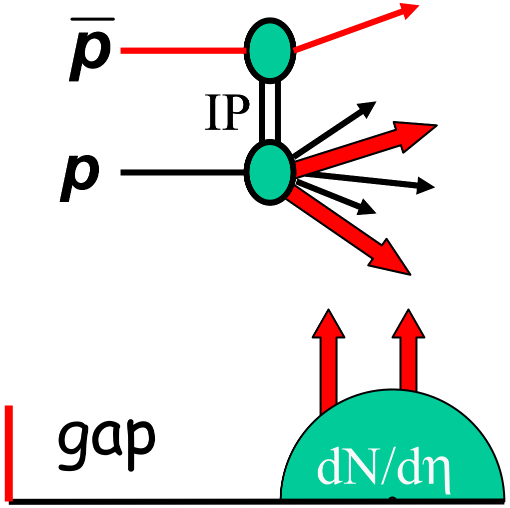
$$R(x) = x^{-0.45}$$

Tevatron vs HERA: Factorization Breakdown

Predicted in KG, PLB 358 (1995) 379

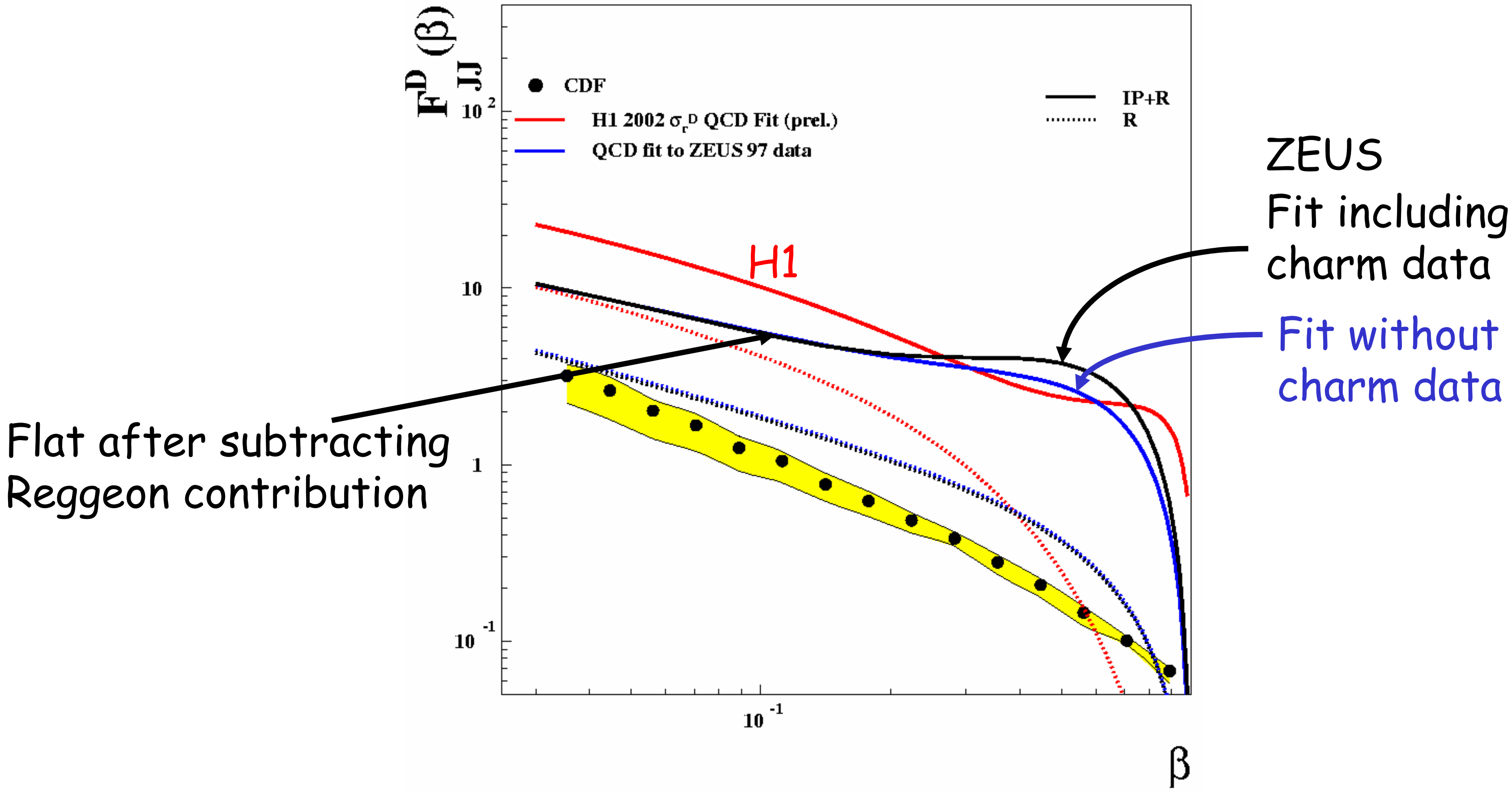




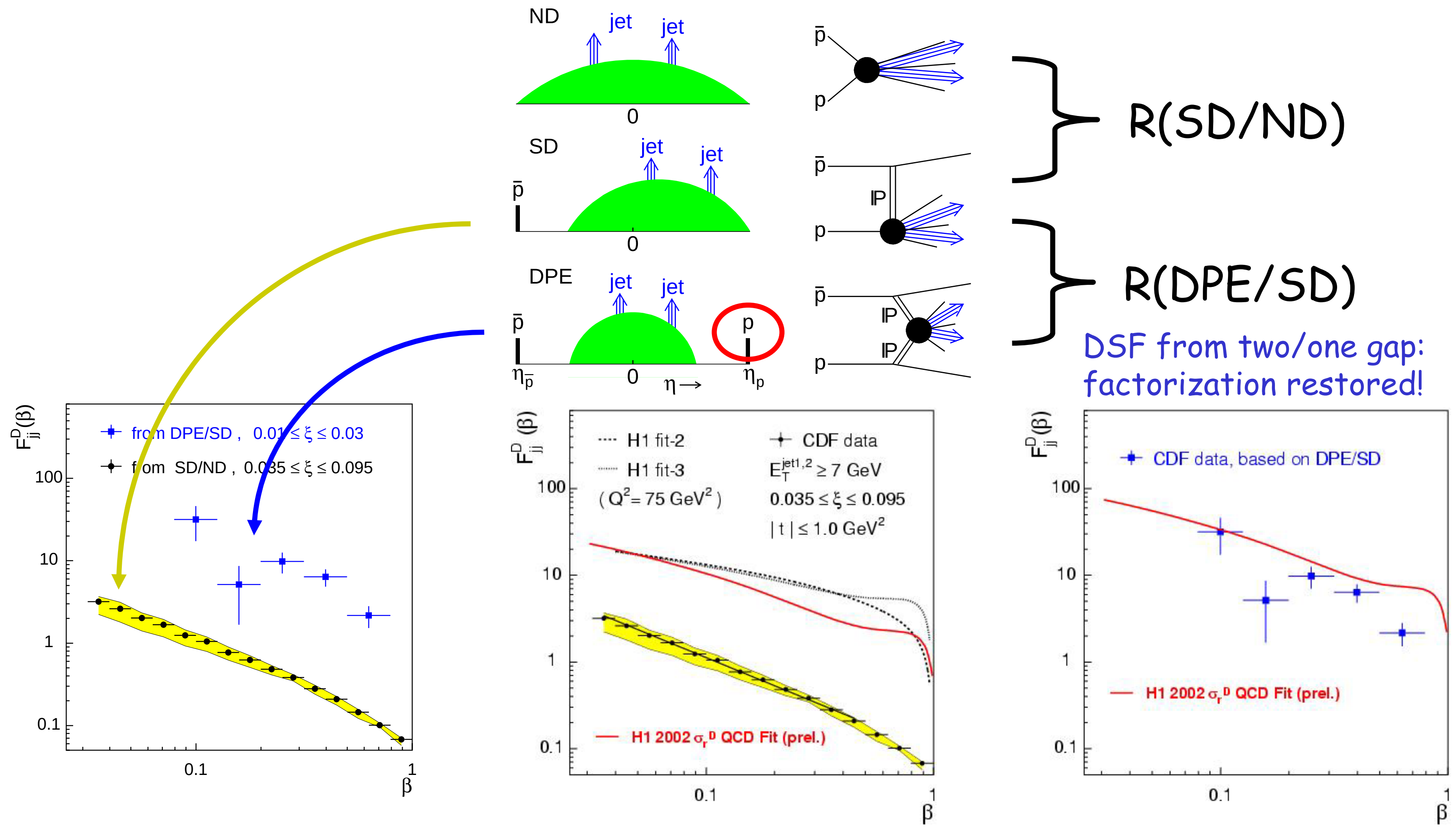


New: $F^D_{JJ}(\beta)$ from ZEUS-LPS Data

M. Arneodo, HERA/LHC workshop, CERN, 11-13 Oct 2004



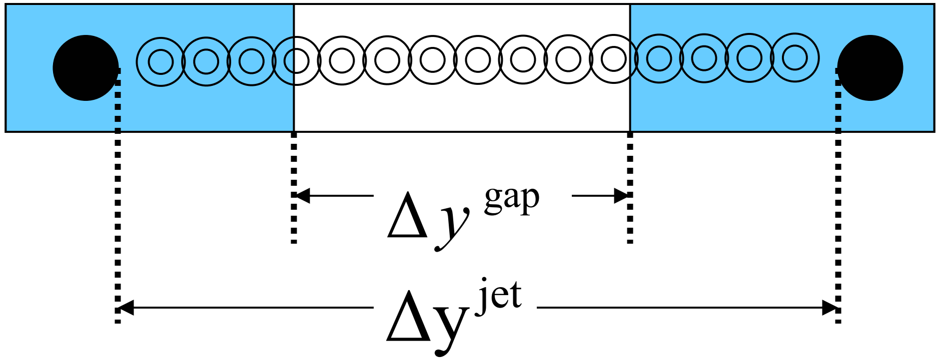
Restoring Factorization @ Tevatron



DSF from two/one gap: factorization restored!

CDF2LHC

TOPIC	STATUS
(Q^2, t) dependence of DSF	close to ready
Exclusive χ_c production	close to ready
Low mass states in DPE	need good trigger
Exclusive b-bbar production in DPE	need b-trigger
ξ -dependence of DSF	need low lum run
Jet-gap-Jet ^{w}/jets in miniplugs	need low lum run



$$\Delta y^{gap} = \Delta y^{jet} \Rightarrow \text{BFKL}$$
$$\Delta y^{gap} \neq \Delta y^{jet} \Rightarrow \text{composite}$$

Diffraction @ LHC

- Multigap diffraction
- Exclusive production of high mass states

Summary

@CDF → Derive diffractive from ND pdf's and color factors

@ LHC → Multigap and High Mass Exclusive Diffraction

CDF2LHC → Special low-lum run needed for low-ξ and JGJ