Multigap Diffraction at the LHC

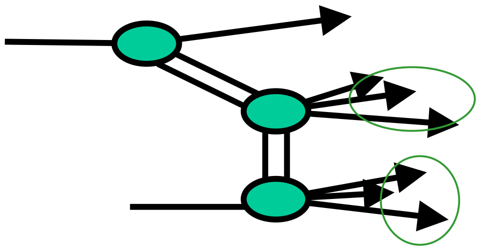
K. Goulianos
The Rockefeller University

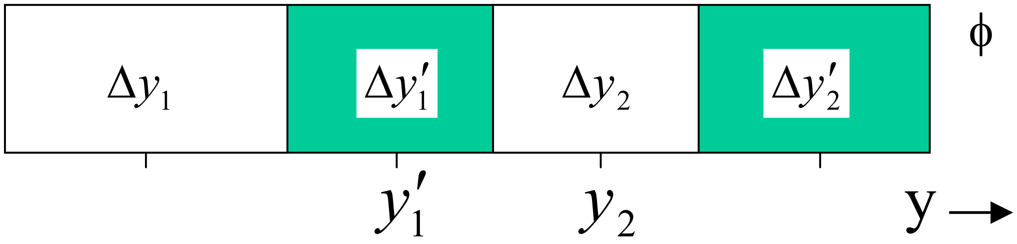
DIS 2005
27 April – 1 May
Madison, Wisconsin

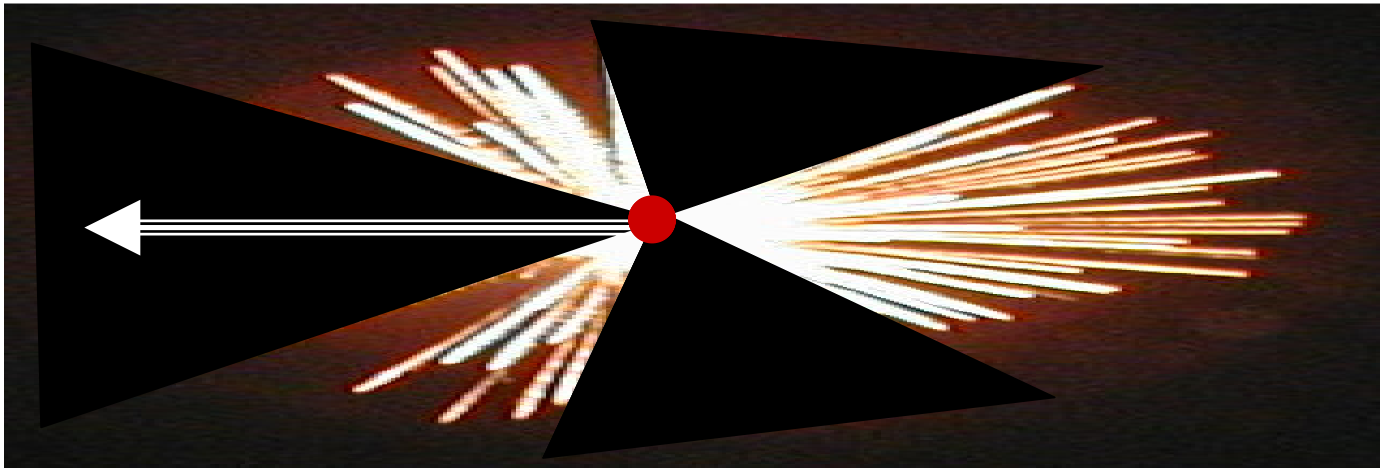
http://physics.rockefeller.edu/dino/my.html

Multigap Diffraction

(KG, hep-ph/0205141)

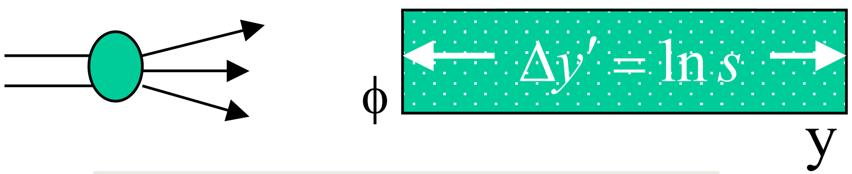






Elastic and Total Cross Sections

QCD expectations

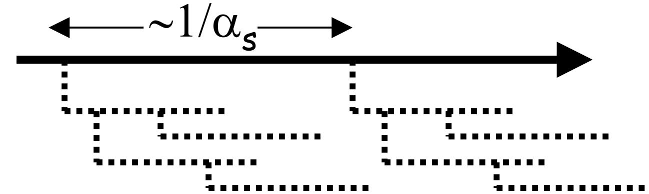


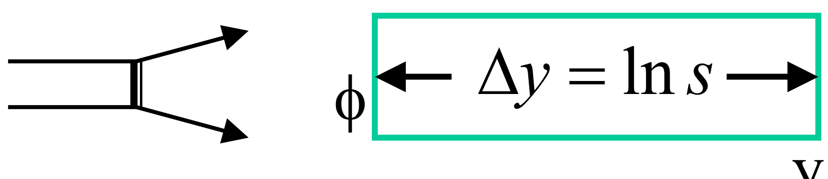
$$\sigma_T(s) = \sigma_o\, s^{\varepsilon} = \sigma_o\, e^{\varepsilon \Delta y'}$$

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)

Total cross section:
power law rise with energy

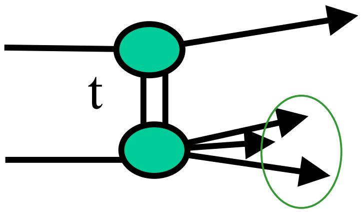


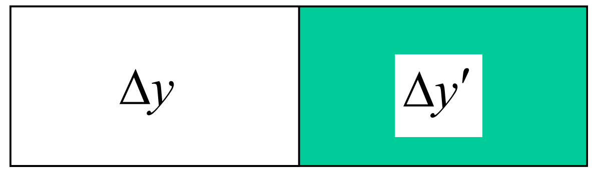


$$\mathrm{Im}\, f_{el}(s,t) \propto e^{(\varepsilon+\alpha' t)\Delta y}$$

Elastic cross section:
forward scattering amplitude

Single Diffraction





2 independent variables: $t, \Delta y$

color factor

$$\kappa = \frac{g_{IP-IP-IP}(t)}{\beta_{IP-p-p}(0)} \approx 0.17$$

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

Gap probability MUST be normalized to unity!

Single diffraction (re)normalized

$$\frac{d^2\sigma}{dt\, d\Delta y} = N_{gap} \cdot \underbrace{C \cdot F_p^2(t) \cdot \left\{e^{(\varepsilon+\alpha' t)\Delta y}\right\}^2}_{P_{gap}(\Delta y, t)} \cdot \kappa \cdot \left\{\sigma_o\, e^{\varepsilon\, \Delta y'}\right\}$$

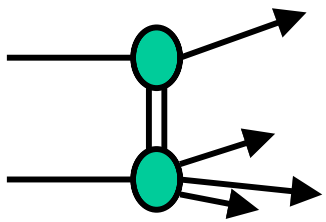
$$N_{gap}^{-1}(s) = \int_{\Delta y, t} P_{gap}(\Delta y, t)\, d\Delta y\, dt \xrightarrow{s\to\infty} C' \cdot \frac{s^{2\varepsilon}}{\ln s}$$

$$\frac{d^2\sigma}{dt\, d\Delta y} = C'' \left[e^{\varepsilon(\Delta y - \ln s)} \cdot \ln s\right] e^{(b_0 + 2\alpha' \Delta y)t}$$

Grows slower than s^ε

→ The Pumplin bound is obeyed at all impact parameters

Total Single Diffractive x-Section



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

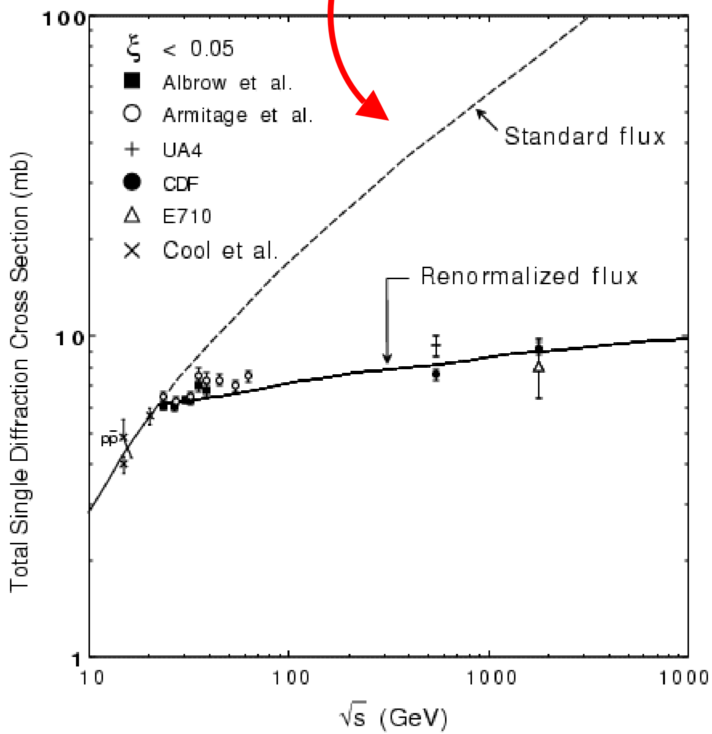
$$\sigma_{SD} \sim s^{2\varepsilon}$$

- **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

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



The Factors κ and ε

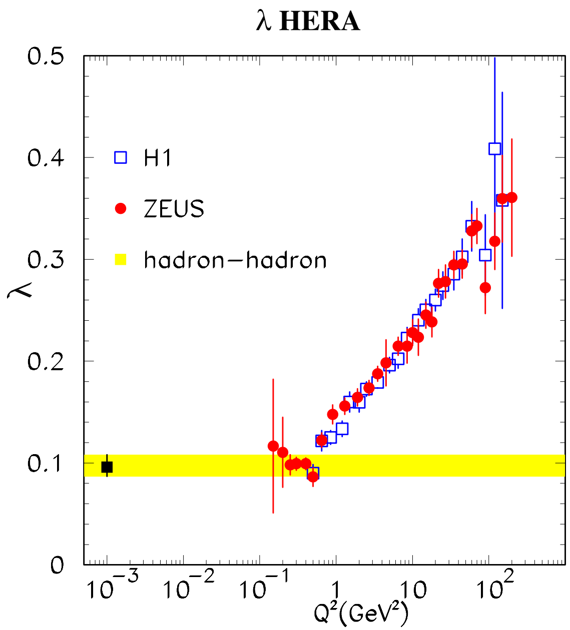
Experimentally:

KG&JM, PRD 59 (114017) 1999

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

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

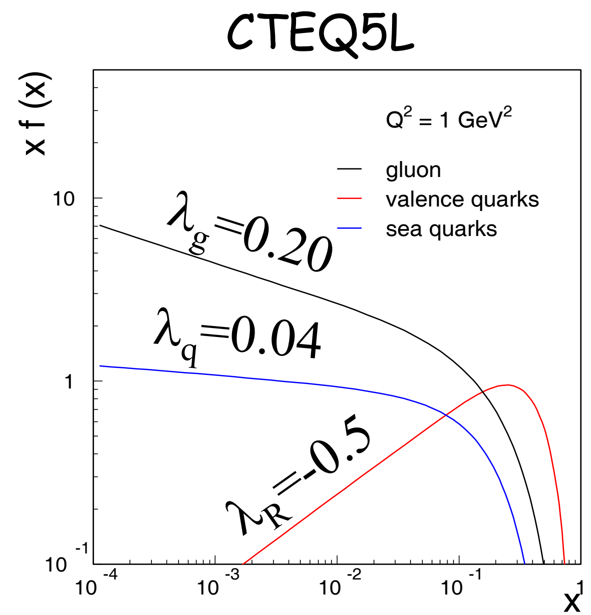
Pomeron intercept: $\varepsilon = \lambda_g \cdot w_g + \lambda_q \cdot w_q = 0.12$



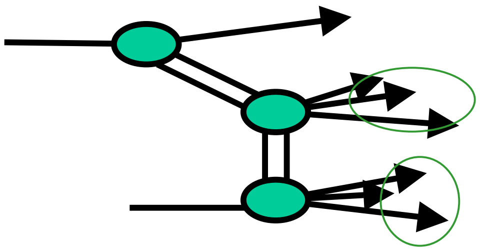
$$x \cdot f(x) = \frac{1}{x^{\lambda}}$$

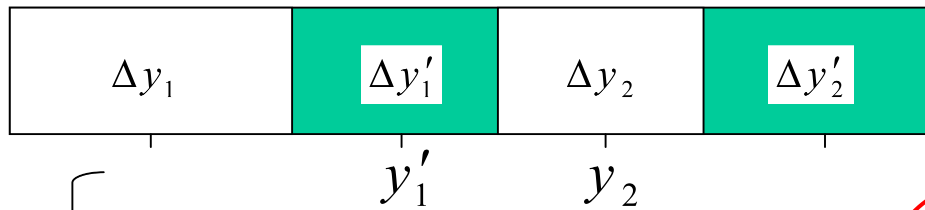
f_g=gluon fraction
f_q=quark fraction

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



Multigap Cross Sections





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

color factors

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

Gap probability

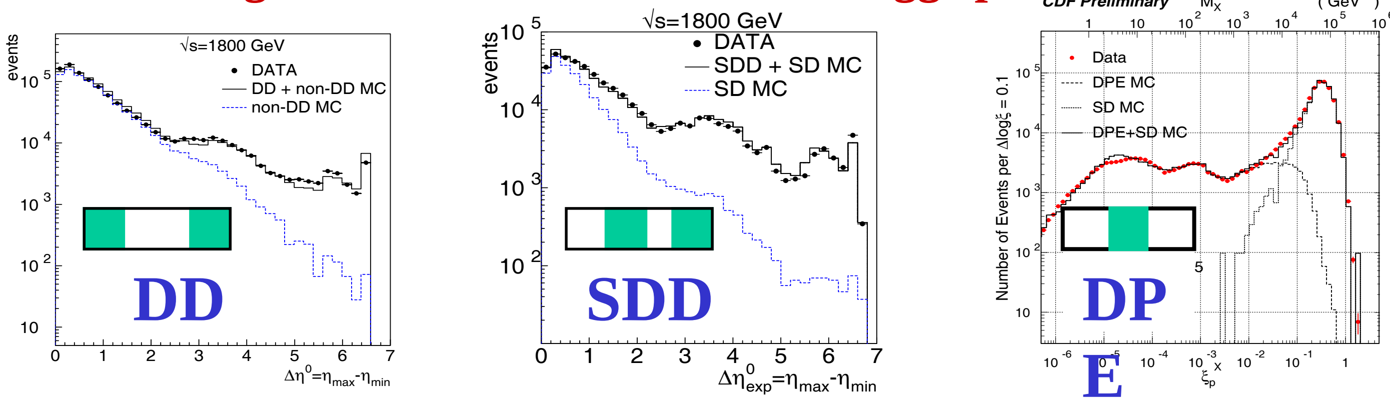
$$\int_{\Delta y, t} \sim s^{2\varepsilon} / \ln s$$

Sub-energy cross section (for regions with particles)

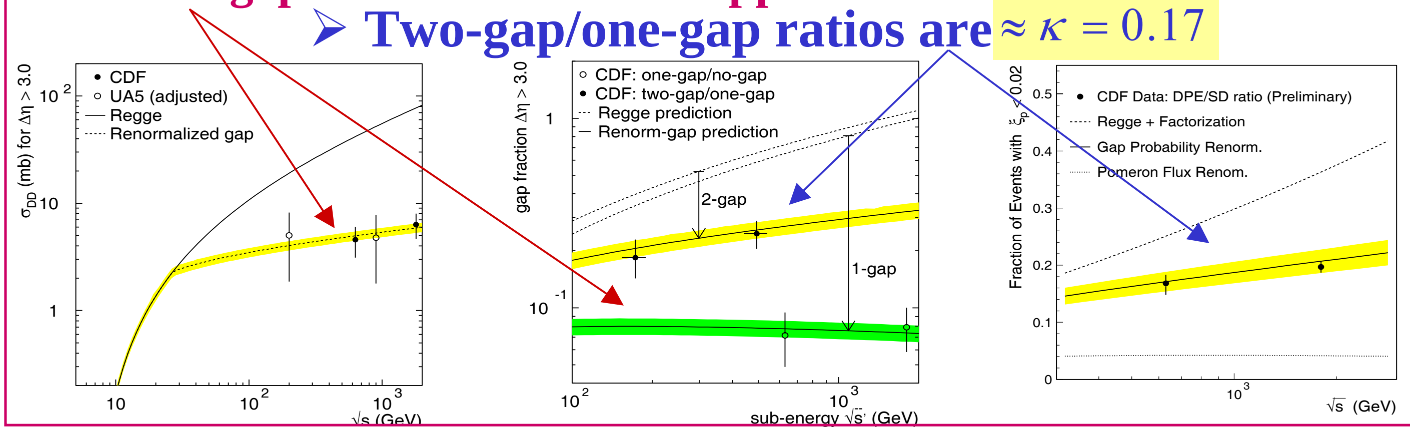
Same suppression as for single gap!

Central and Two-Gap CDF Results

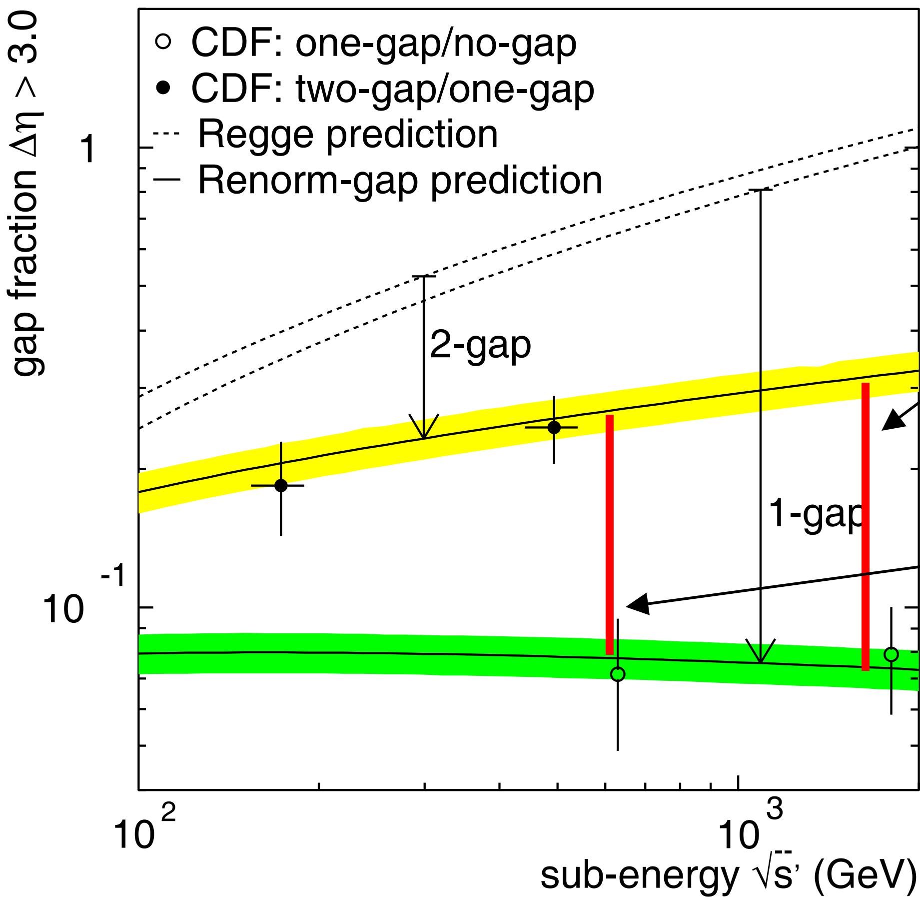
Agreement with renormalized Regge predictions

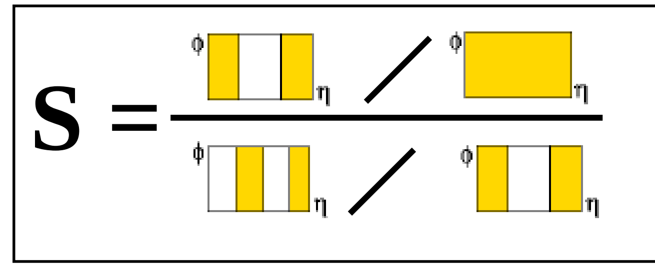


- **One-gap cross sections are suppressed**
- **Two-gap/one-gap ratios are $\approx \kappa = 0.17$**



Gap Survival Probability





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

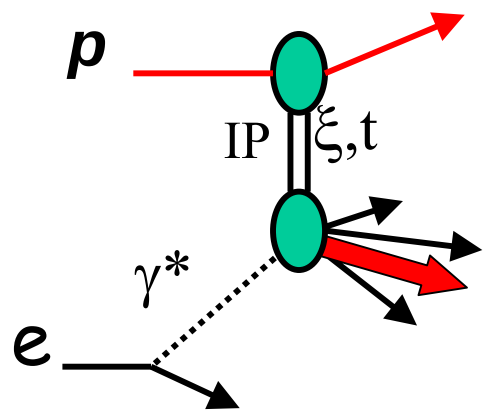
$$S^{1-\text{gap}/0-\text{gap}}_{2-\text{gap}/1-\text{gap}}(630\ \text{GeV}) \approx 0.29$$

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

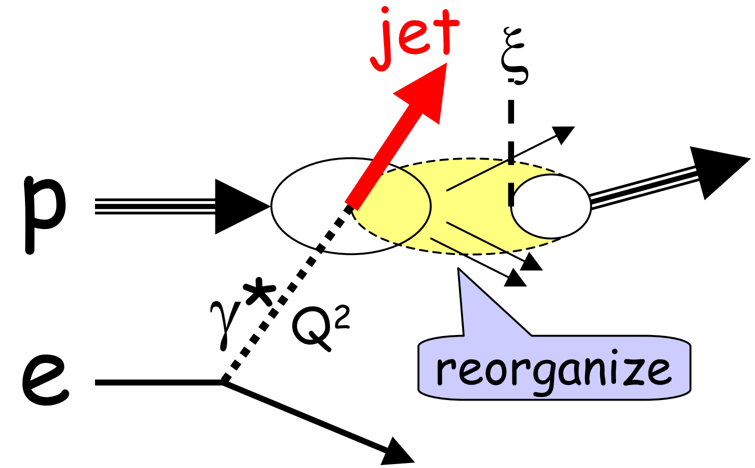
Diffractive DIS @ HERA

Factorization holds: J. Collins

Pomeron exchange



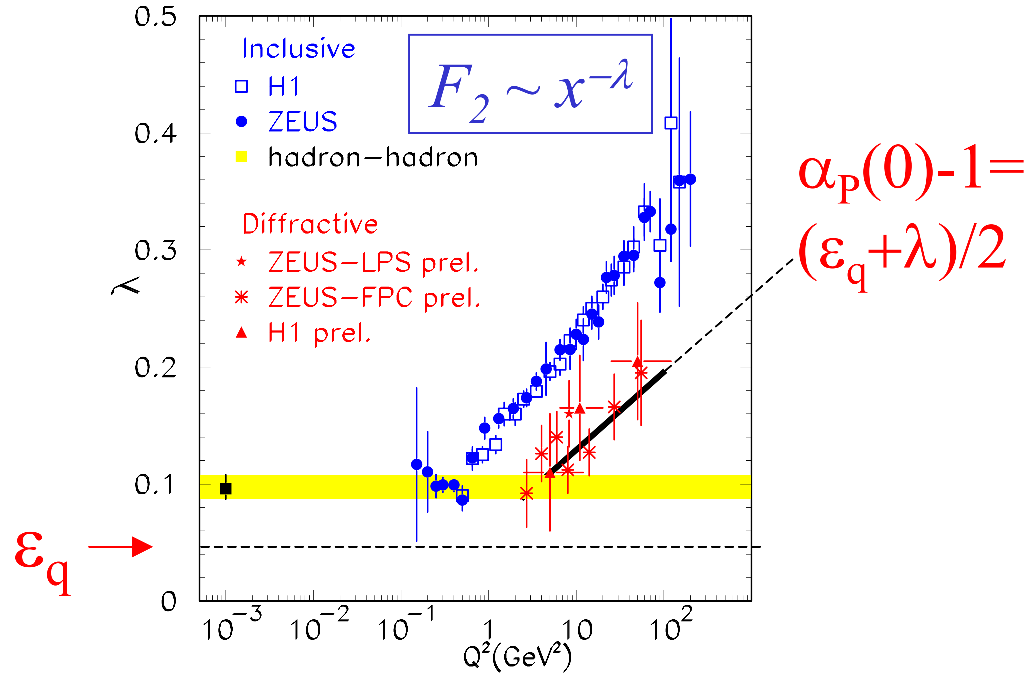
Color reorganization



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

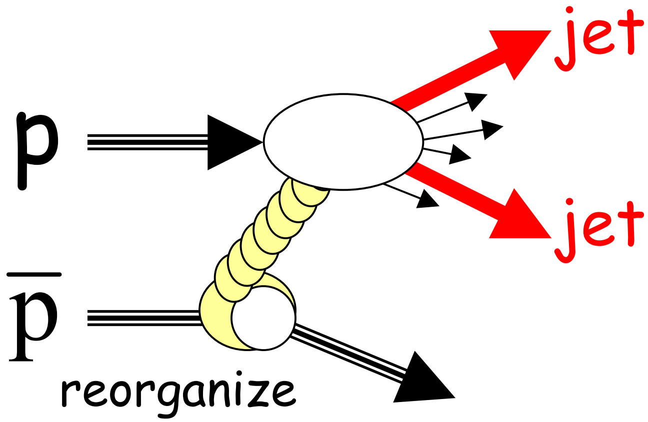
Inclusive vs Diffractive DIS

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



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

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

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

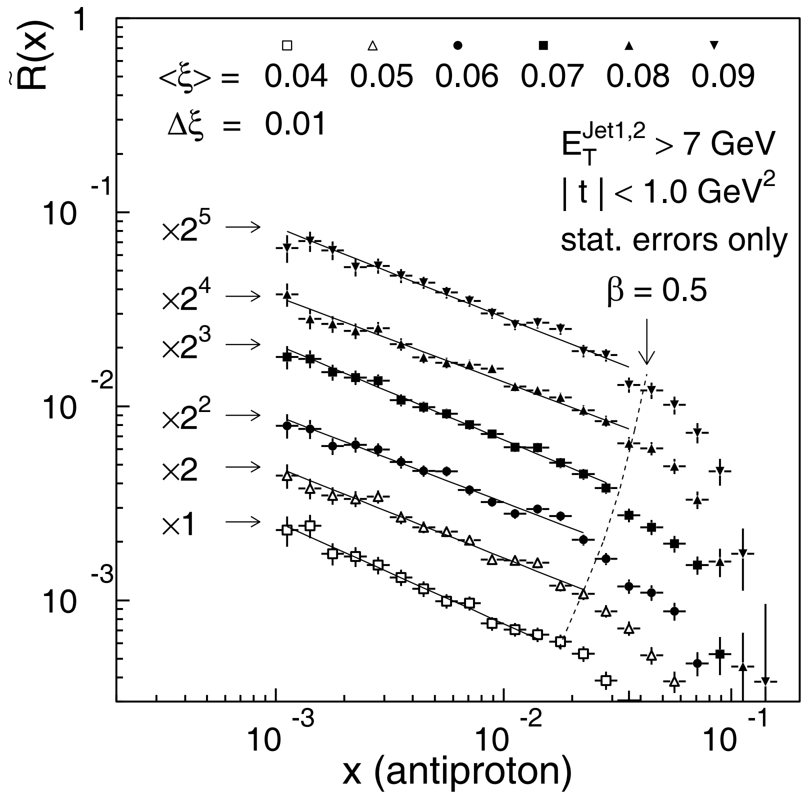
$$\mathrm{N}^{-1}_{\mathrm{renorm}} = \int_{\xi_{\min}}^{1} \frac{d\xi}{\xi^{1+2\varepsilon}} \xrightarrow{\xi_{\min} = \frac{x_{\min}}{\beta} \approx \frac{1}{\beta\, s}} \frac{(\beta\, s)^{2\varepsilon}}{2\varepsilon}$$

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

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

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

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

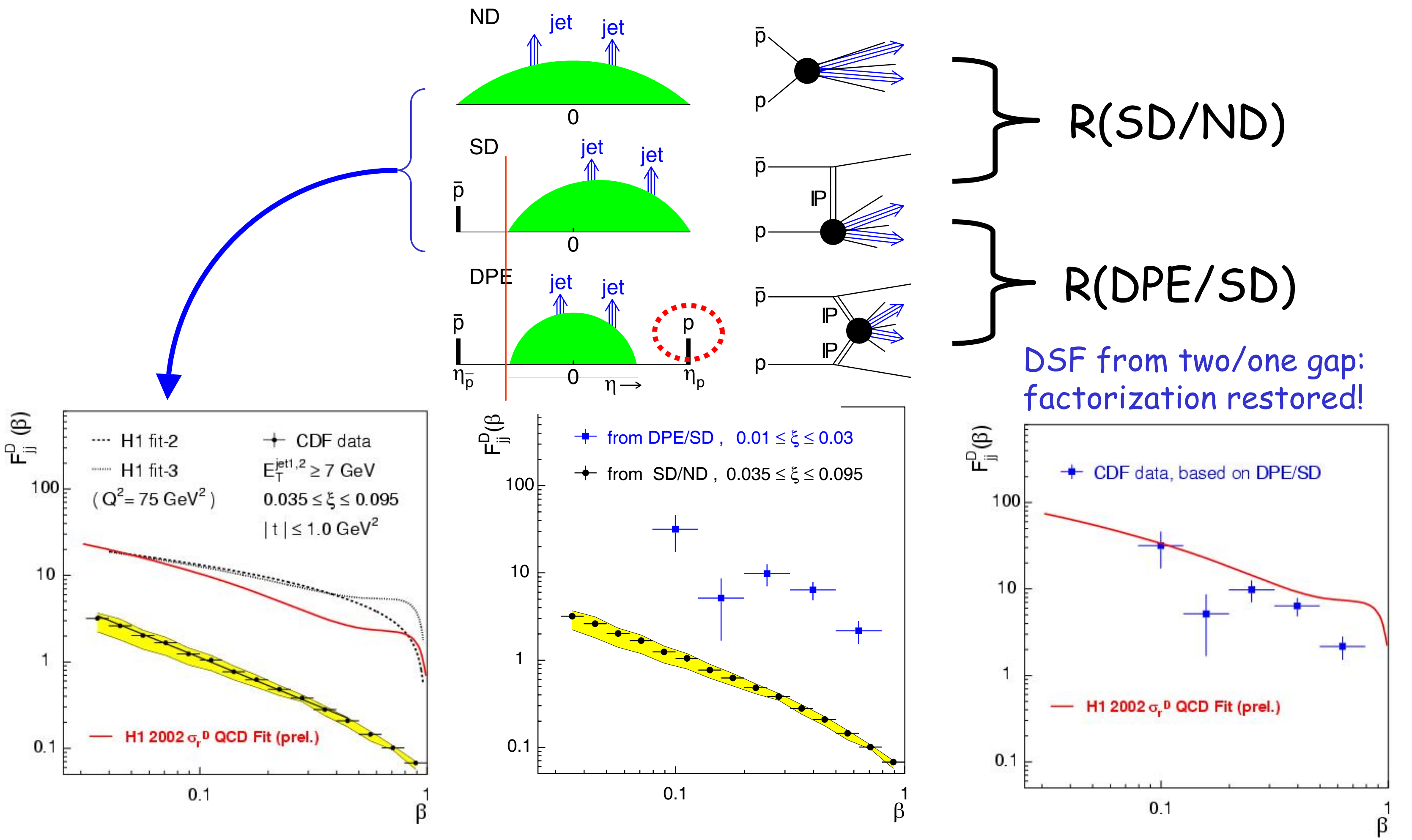


$0.035 < \xi < 0.095$

Flat ξ dependence

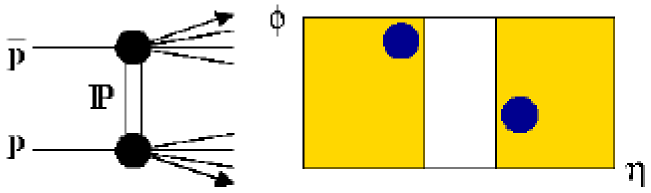
$$R(x) = x^{-0.45}$$

Restoring Factorization @ Tevatron

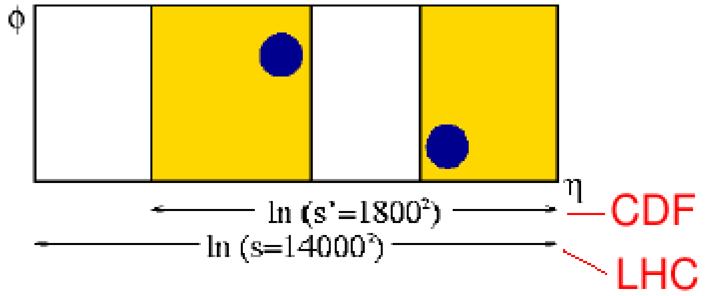


Gap Between Jets

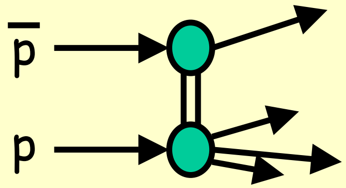
$$\bar{p} + p \rightarrow \text{Jet} + \text{Gap} + \text{Jet}$$



$$R^{J-G-J}_{TEV}(s') \approx 1\%/$$

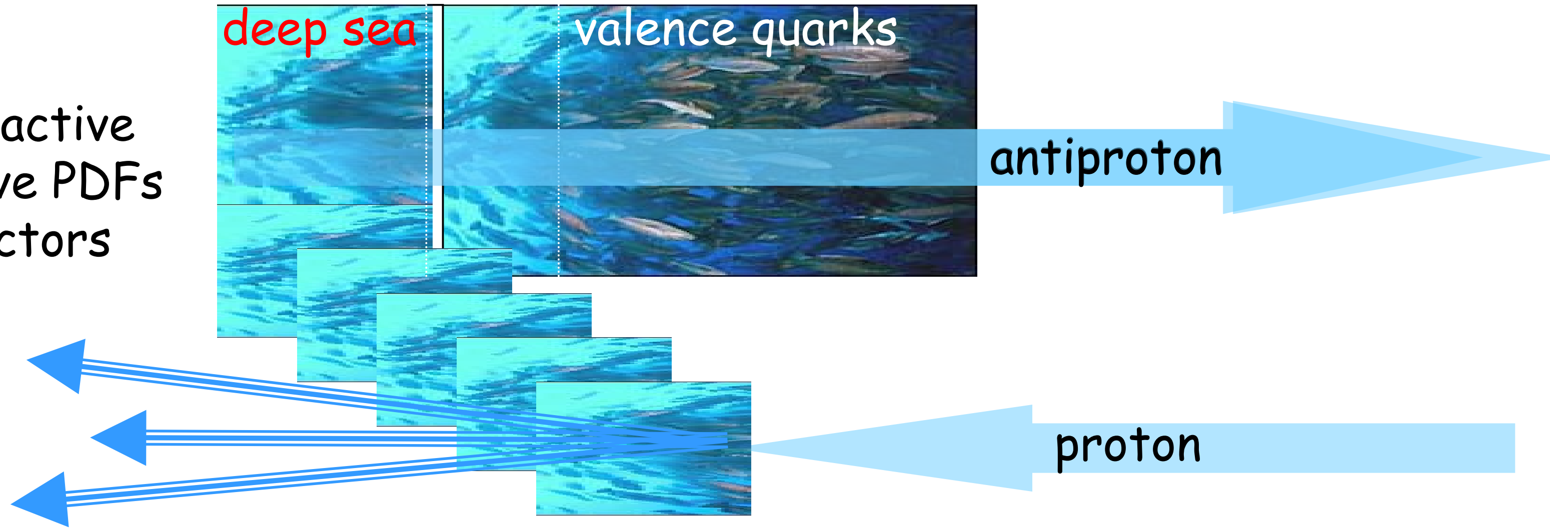


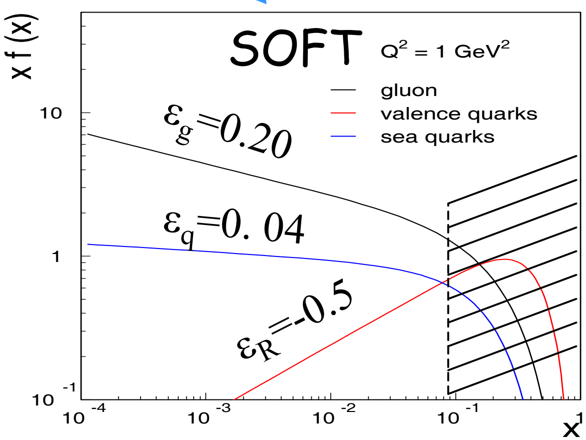
$$R^{J-G-J}_{LHC}(s') = \frac{R^{J-G-J}_{TEV}}{S} \approx \frac{1\%}{0.2} \approx 5\%$$



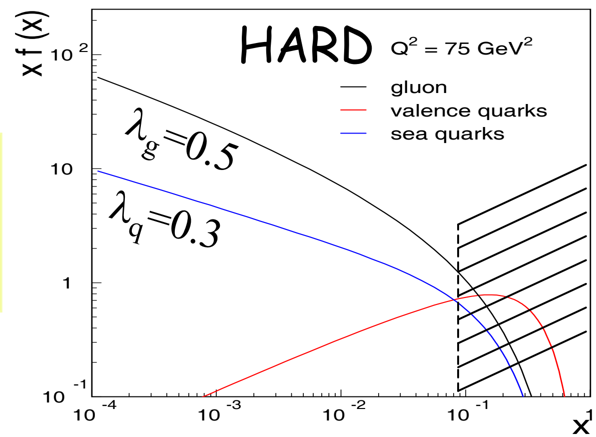
Low-x and Diffraction

Derive diffractive from inclusive PDFs and color factors





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



Summary

- Multigap processes offer the opportunity of studying diffraction without complications arising from screening corrections, multi-Pomeron exchanges, rescattering, or other rapidity gap survival issues.

- Run 1 results from the Tevatron, and those expected from Run 2, should be followed up by more studies at the LHC with the aim of advancing a successful phenomenology to a THEORY of diffraction.

Thanks to
The Rockefeller HEP Group

Anwar Luc Stefano Michele Mary Koji Christina Andrea Ken