Small-x and Diffraction 2003
Fermilab, Illinois, USA

Soft Double Pomeron Exchange in CDF Run I

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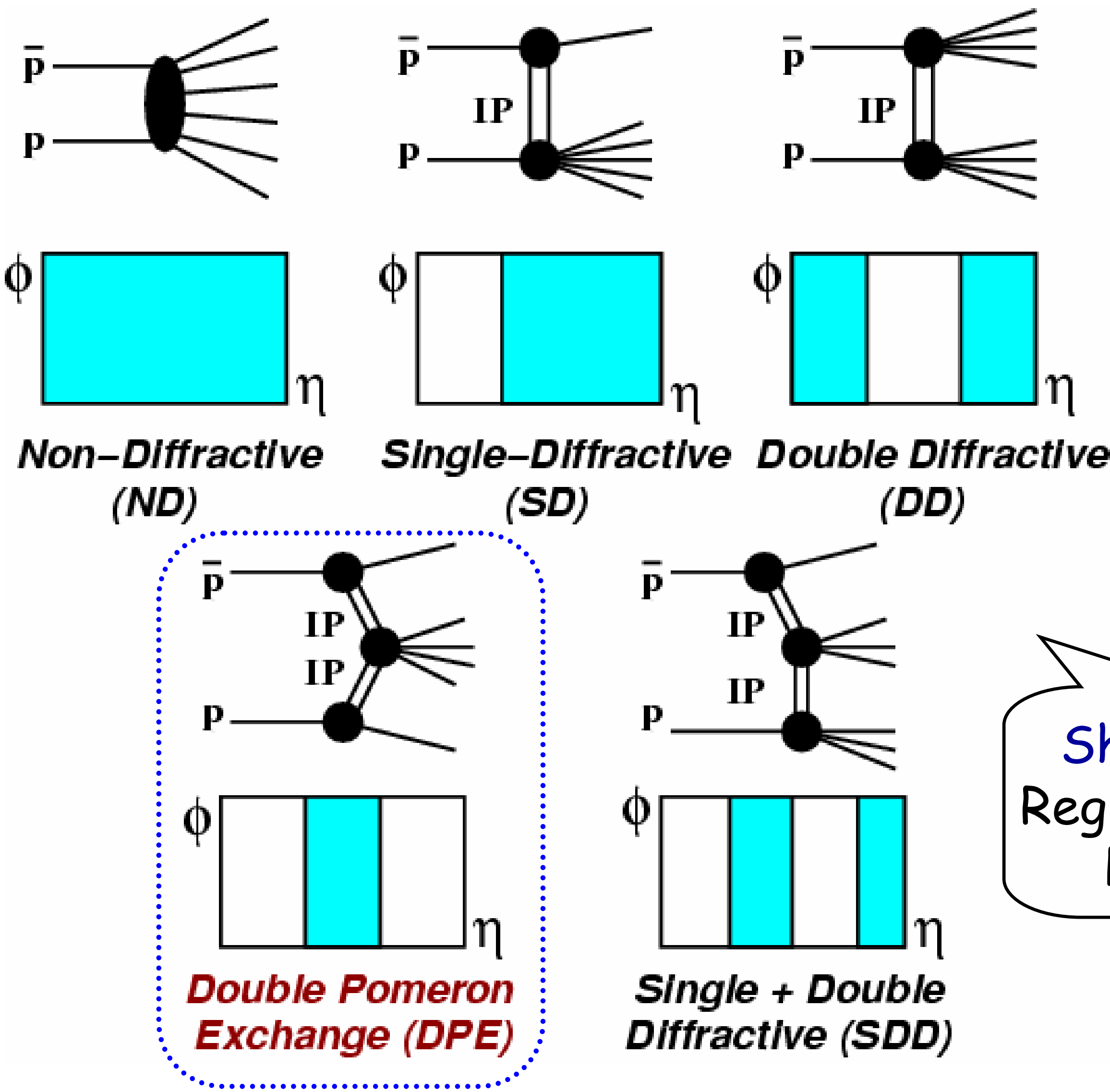
Introduction



Shaded Area :
Region of Particle Production

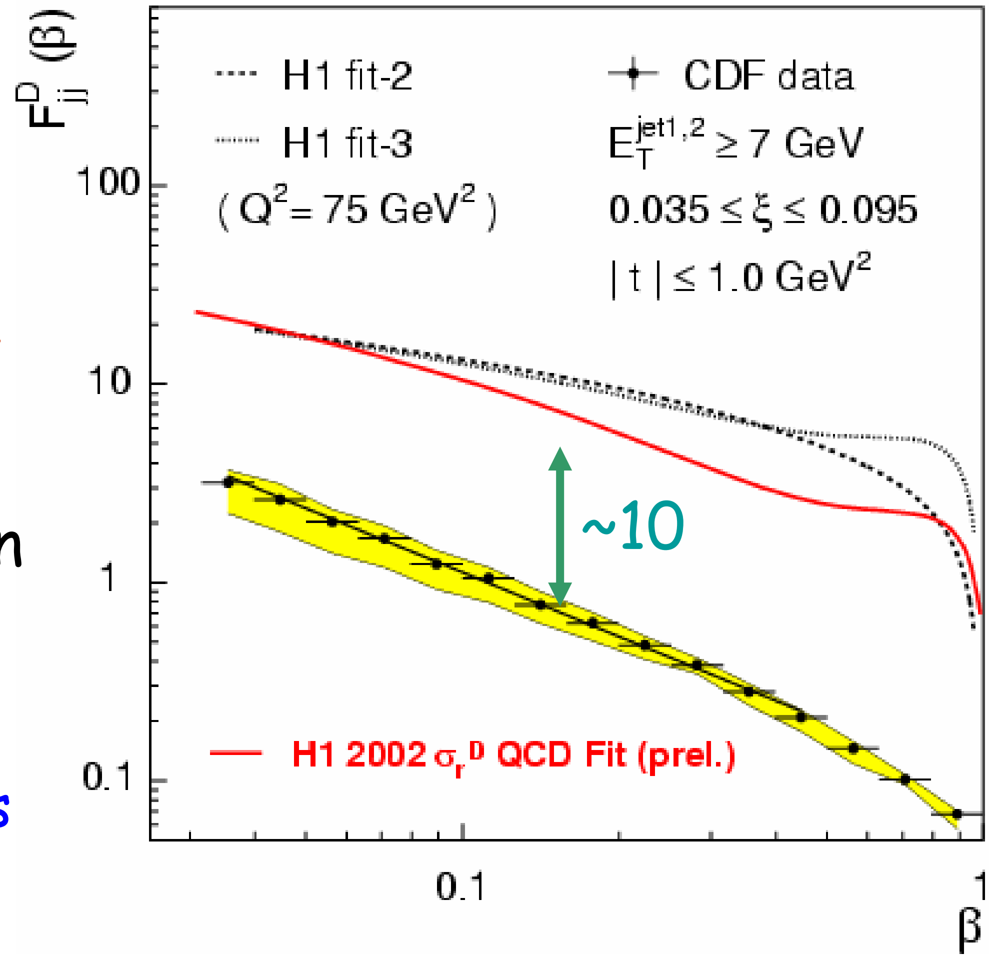
Main Issue in Hadronic Diffraction :

results from single diffractive (SD) dijet production

CDF Collaboration, Phys. Rev. Lett. 84, 5043-5048 (2000).

- The diffractive structure function measured using SD dijet events at the Tevatron is smaller than that at HERA by approximately an order of magnitude.

Factorization Breakdown

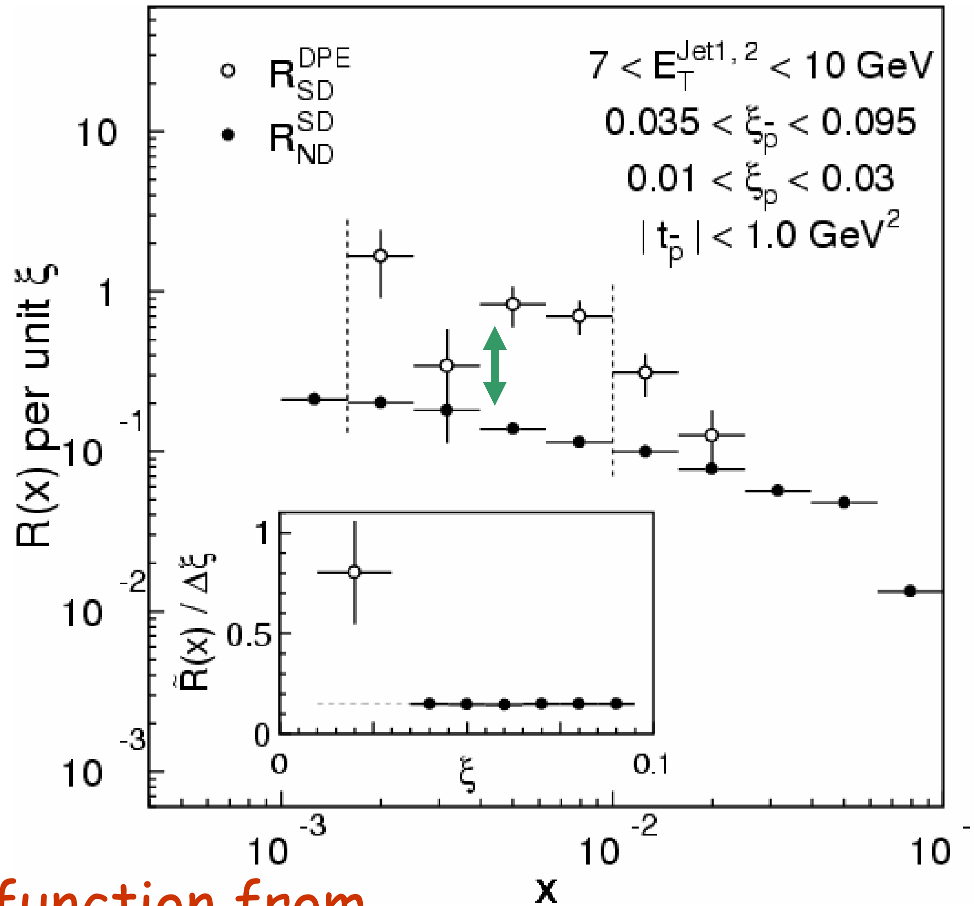


- The discrepancy is generally attributed to additional color exchanges which spoil the "diffractive" rapidity gap.

Dijet Production in DPE

CDF Collaboration, Phys. Rev. Lett. 85, 4215-4220 (2000).

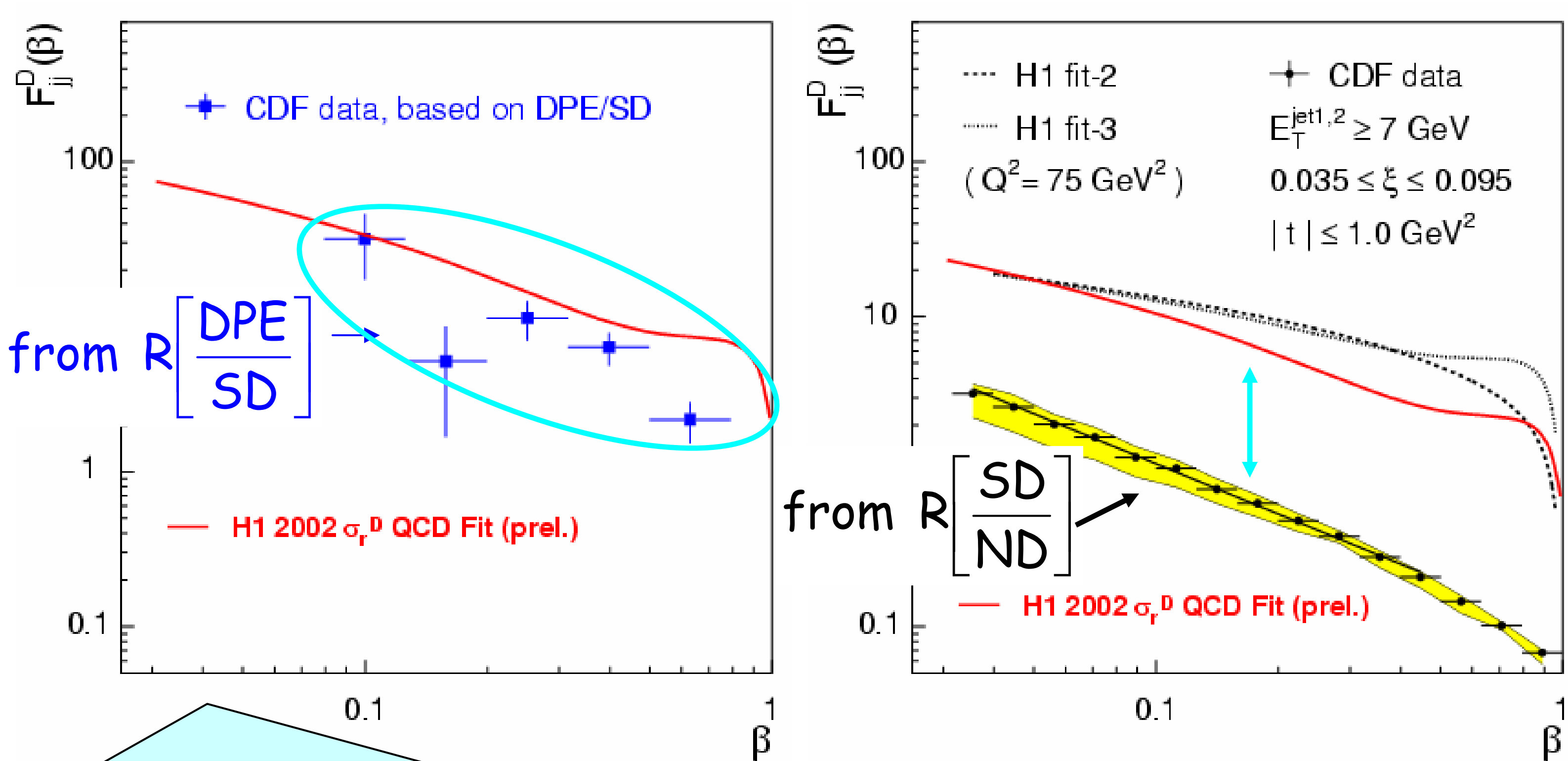
- Dijet production by double pomeron exchange was studied by CDF.
- R[DPE/SD] is larger than R[SD/ND] by a factor of about 5.



The formation of the 2nd gap is not as suppressed as the 1st gap.

Extract diffractive structure function from R[DPE/SD] and compare it with expectations from HERA results.

Diffractive Structure Function measured using DPE dijet events



The diffractive structure function measured using DPE dijets is approximately equal to expectations from HERA!

→ Factorization holds?

Soft Diffraction : Inclusive (Soft) SD Results

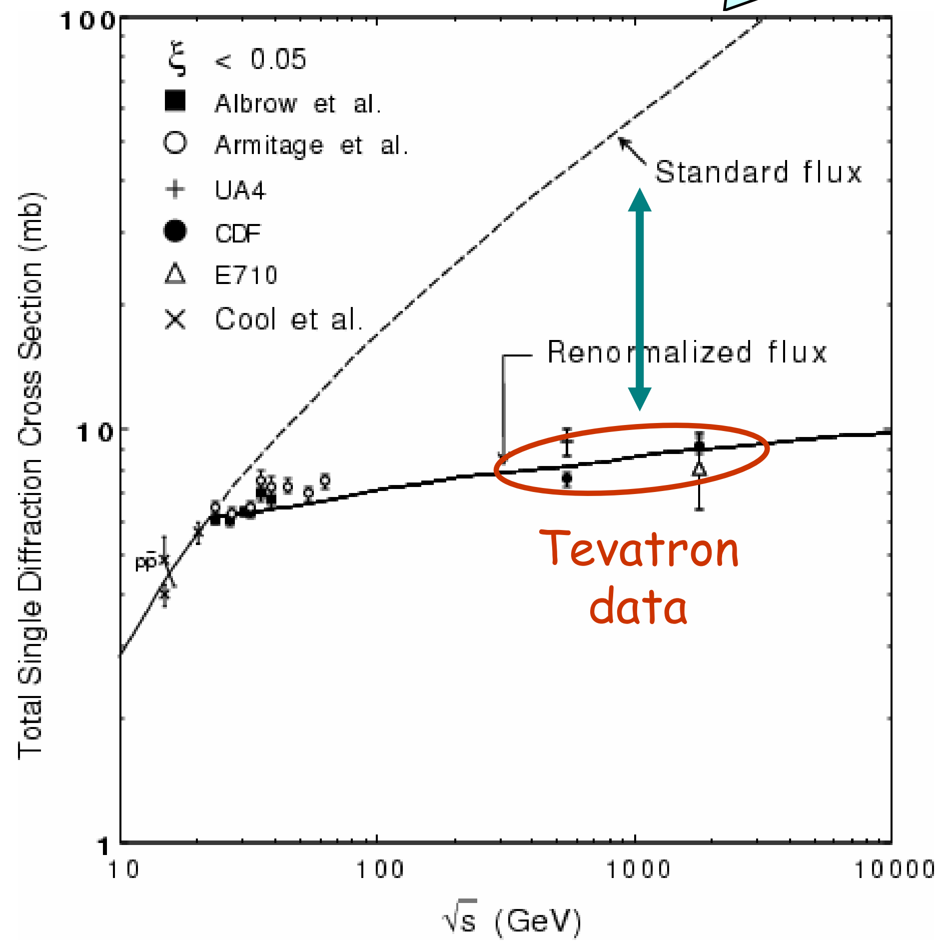
Unitarity problem : $\sigma_{SD}/\sigma_{tot} \to 1$ at $\sqrt{s} \approx 2\text{TeV}$.

- The measured SD cross section is smaller than the Regge theory prediction by approximately an order of magnitude at the Tevatron energy.

$$\frac{d^2\sigma_{SD}}{dtd\xi} = f_{IP/p}(t,\xi) \cdot \sigma_{IP-\bar{p}}(s'=\xi s).$$

- Normalizing the integral of the pomeron flux ($f_{IP/p}$) to unity yields the correct $\sqrt{s}$-dependence of σ_{SD}.

⇒ Renormalization

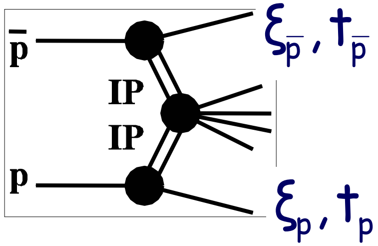


Similar results were obtained for double diffraction as well.

Is the formation of the second gap suppressed? ⇒ Study DPE

Inclusive (Soft) DPE Cross Section

⇨ Regge theory prediction + factorization :



$$\frac{d^4\sigma_{DPE}}{d\xi_{\bar{p}}d\xi_p dt_{\bar{p}}dt_p} = \underbrace{f_{IP/\bar{p}}(\xi_{\bar{p}}, t_{\bar{p}}) f_{IP/p}(\xi_p, t_p)}\left(\kappa^2\beta^2(0)(s')^{\varepsilon}\right),$$

$$\parallel$$

$$\frac{d^4\sigma_{DPE}}{d\xi_{\bar{p}}d\xi_p dt_{\bar{p}}dt_p} = \underbrace{\left[\prod_{i=\bar{p},p}\frac{\beta(t_i)}{4\sqrt{\pi}}e^{[\alpha(t_i)-1]\Delta y_i}\right]^2}_{P_{gap}}\left(\kappa^2\beta^2(0)(s')^{\varepsilon}\right),$$

$\xi_{p(\bar{p})}$: fractional momentum loss of $p(\bar{p})$,

$f_{IP/p(\bar{p})}$: Pomeron flux,

$\beta(t)$: $IP - p(\bar{p})$ coupling,

g:triple-Pomeron coupling,

$\kappa = g/\beta(0)$.

$$\frac{\sigma_{DPE}}{\sigma_{SD}} \approx 0.36 \text{ at } \sqrt{s} = 1800 \text{ GeV}.$$

⇨ Flux renorm. model : Both $f_{IP/p}$ and $f_{IP/\bar{p}}$ are renormalized independently. (both gaps are suppressed.) K. Goulianos, Phys. Lett. B 353, 379 (1995).

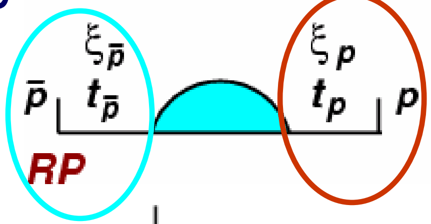
$$\frac{\sigma_{DPE}}{\sigma_{SD}} \approx 0.041 \text{ at } \sqrt{s} = 1800 \text{ GeV}.$$

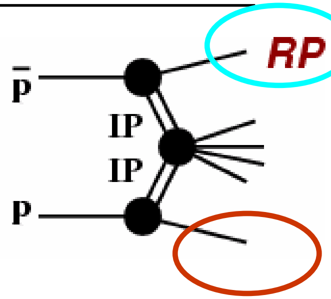
⇨ Gap probability (P_{gap}) renorm. model : P_{gap} is renormalized. (only one gap is suppressed.) K. Goulianos, e.g. hep-ph/0110240 (2001).

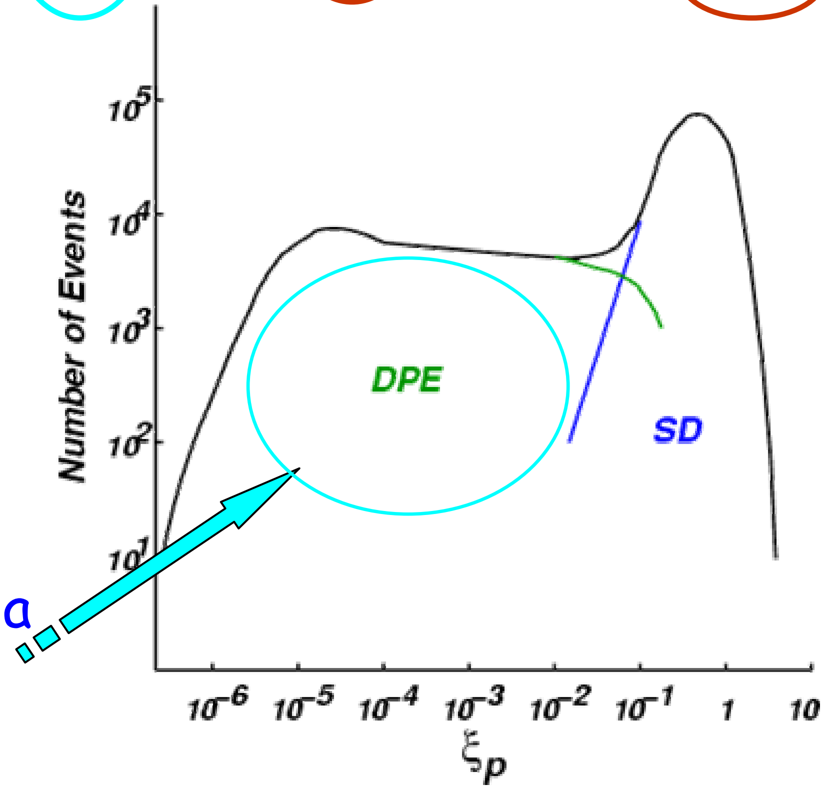
$$\frac{\sigma_{DPE}}{\sigma_{SD}} \approx 0.21 \text{ at } \sqrt{s} = 1800 \text{ GeV}.$$

Analysis Strategy

- Use events triggered on a leading antiproton.
- ξ_{pbar} is measured by Roman Pots : ξ_{pbar}^{RPS}.
- Measure ξ_p (ξ_{pbar}) from BBC and calorimeters : ξ_p^X (ξ_{pbar}^X).
- Calibrate ξ^X by comparing ξ_{pbar}^{RPS} and ξ_{pbar}^X.
- Plot ξ_p^X distribution and look for a DPE signal expected in the small ξ_p^X region.

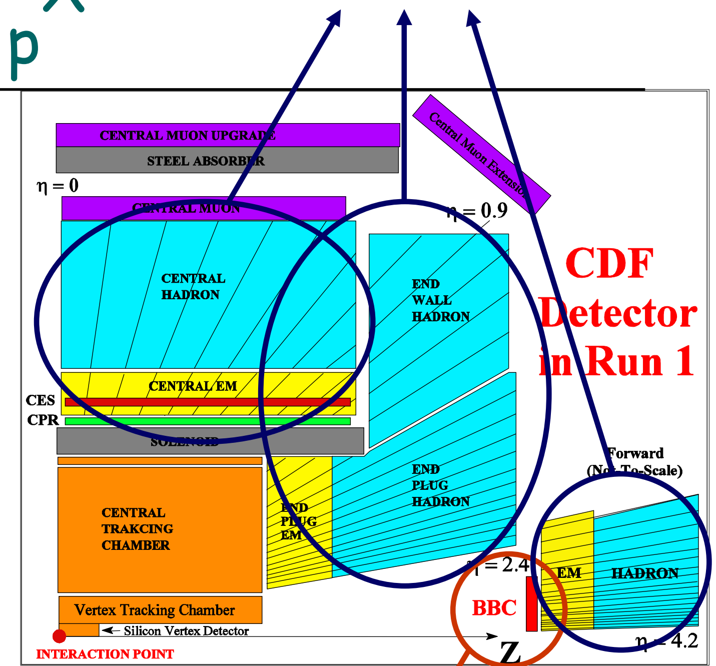






Reconstruction of ξ_p^X

Calorimeters



Use calorimeter towers and BBC hits to reconstruct ξ_p :

$$\xi_p^X = \frac{\sum_i E_{T,i} \exp(+\eta_i)}{\sqrt{s}}.$$

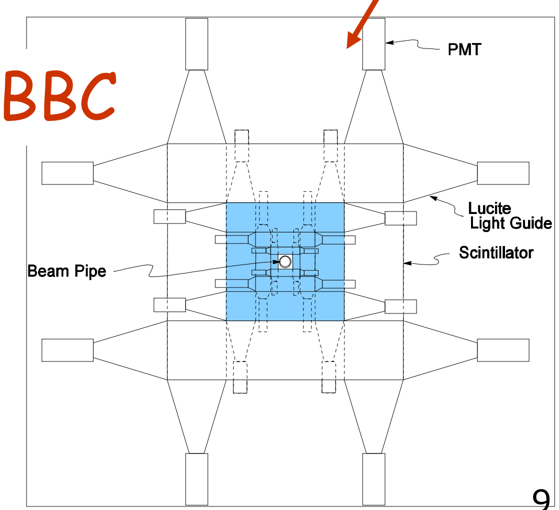
Calorimeters : use E_T and η of towers above noise level.

BBC : use hits in BBC scintillation arrays.

- p_T is chosen to follow the "known" p_T spectrum :

$$\frac{d\sigma}{dp_T} = p_T(1 + p_T/1.27)^{-[4+35.8/\ln(M/0.3)]}.$$

BBC

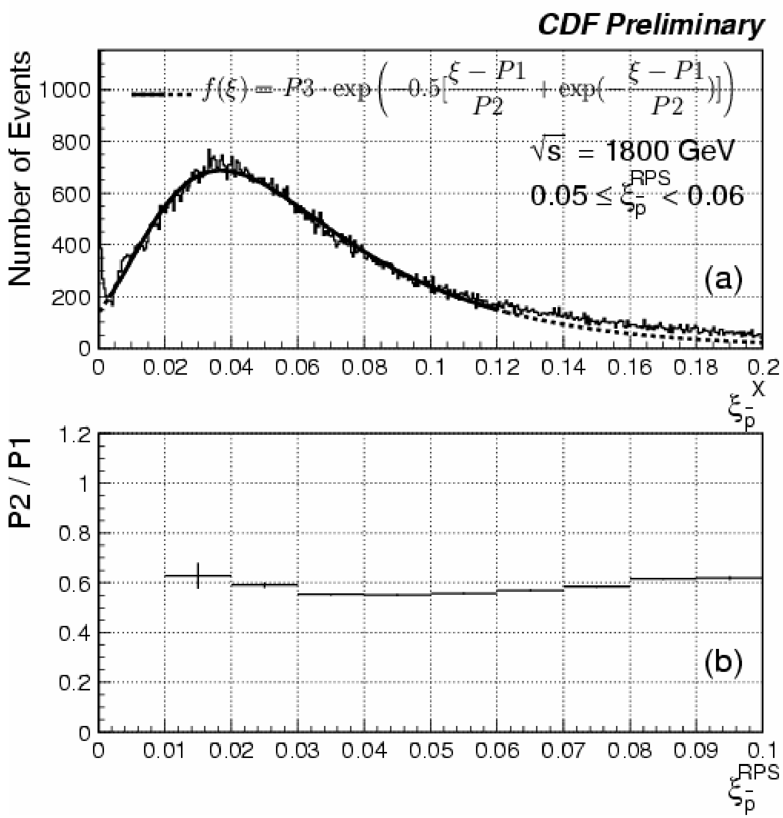


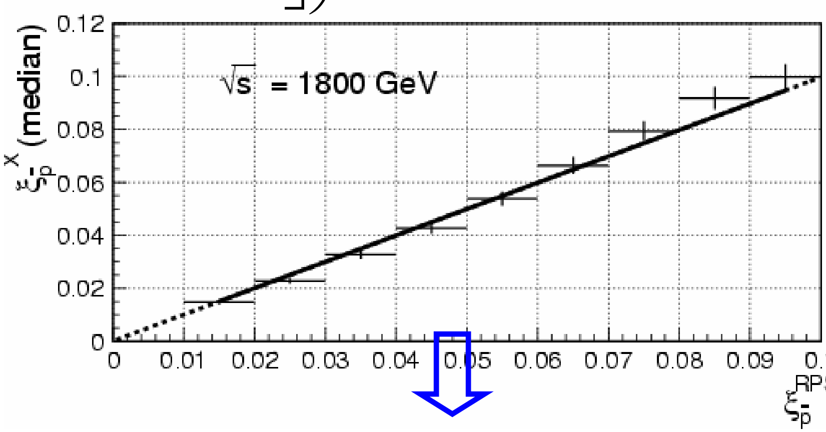
Calibration of ξ^X

ξ^X distribution in every ξ^{RPS} bin is fitted to

$$f(\xi) = P3\exp\left(-0.5\left[\frac{\xi - P1}{P2} + \exp\left(-\frac{\xi - P1}{P2}\right)\right]\right).$$

P1 : Peak
P2 : Width



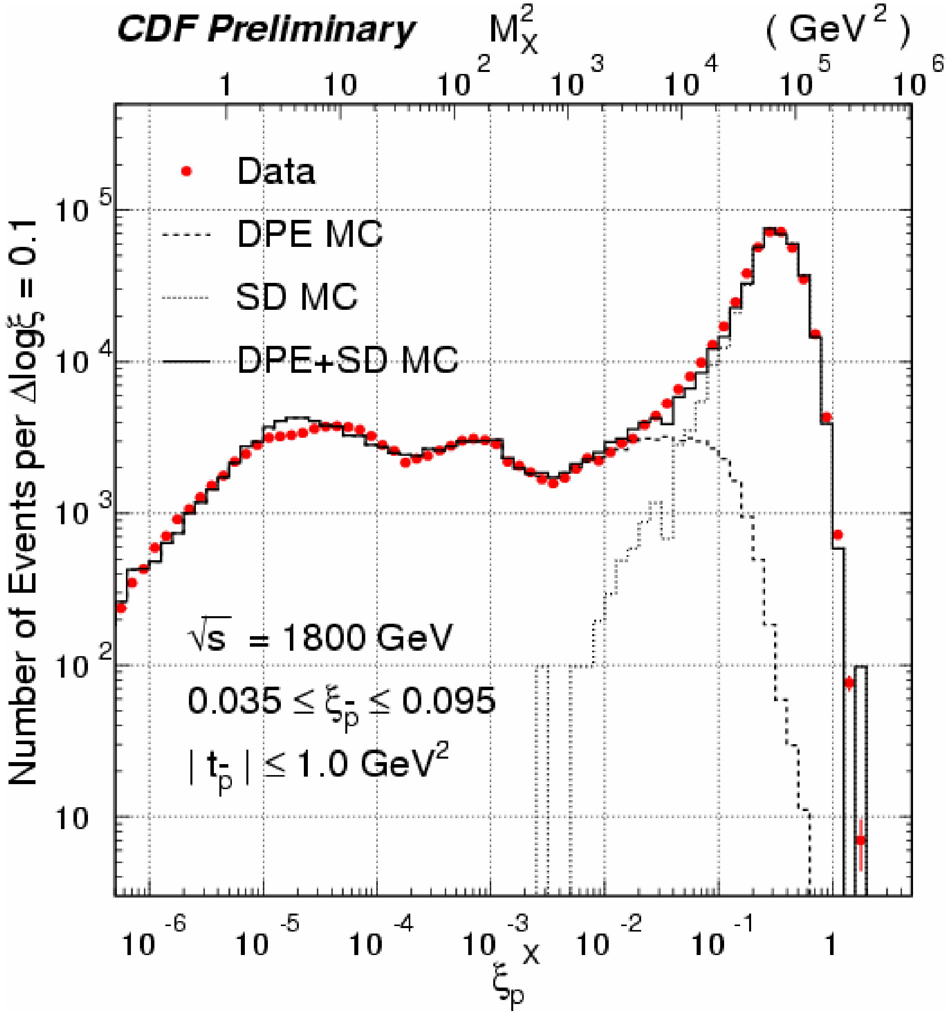


$\xi^X = \xi^{RPS}$,
(ξ^X is calibrated so that $\xi^X = \xi^{RPS}$.)

P2/P1 = 0.57
(ξ^X resolution is ~60%.)

ξ_p^X Distribution

- The input ξ_p distribution in DPE MC is $1/\xi_p^{1+\varepsilon}$ (ε = 0.104 is obtained from $p^{\pm}p/\pi^{\pm}p/K^{\pm}p$ total cross sections).
- The DPE and SD MC distributions are independently normalized to the data distribution.
- The measured ξ_p^X distribution is in agreement with the DPE+SD MC distribution.



DPE Fraction in SD Events

$$0.035 < \xi_{\bar{p}} < 0.095, \qquad \xi_p < 0.02$$

$$R\left[\frac{DPE}{SD(incl)}\right] = 0.195 \pm 0.001(stat) \pm 0.011(syst)$$

$$\text{at } \sqrt{s} = 1800 \text{ GeV.}$$

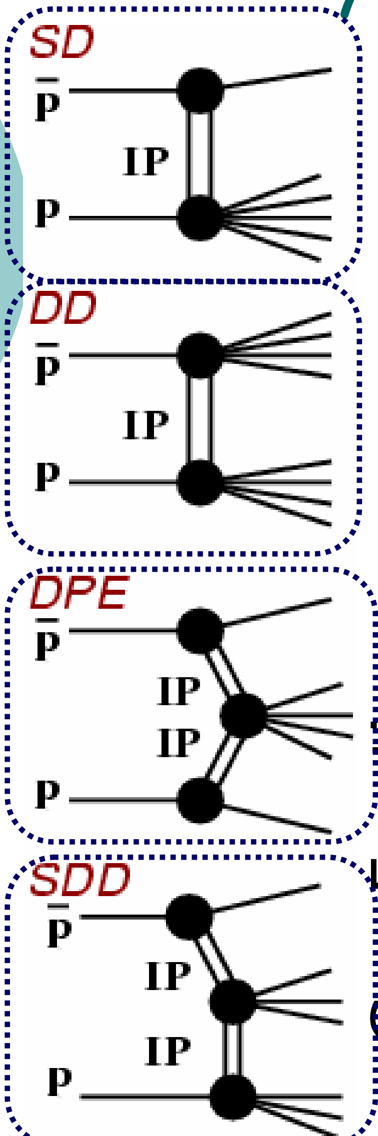
$$\left(R\left[\frac{DPE}{SD(incl)}\right] = 0.168 \pm 0.001(stat) \pm 0.012(syst) \text{ at } \sqrt{s} = 630 \text{ GeV.} \right)$$

	R[DPE/SD(incl)]	
Source	@ 1800 GeV	@ 630 GeV
Data	0.195±0.001±0.011	0.168±0.001±0.012
Regge + factorization	0.36	0.25
Flux Renormalization	0.041	0.041
P_{gap} Renormalization	0.21	0.17

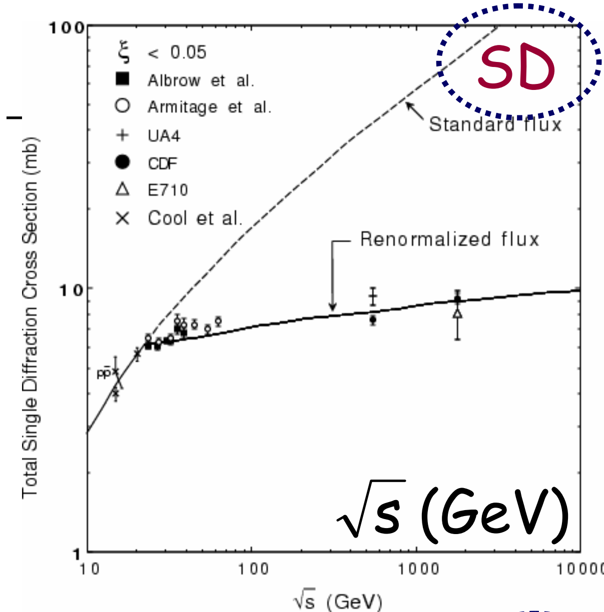
In agreement with the renormalized gap predictions!

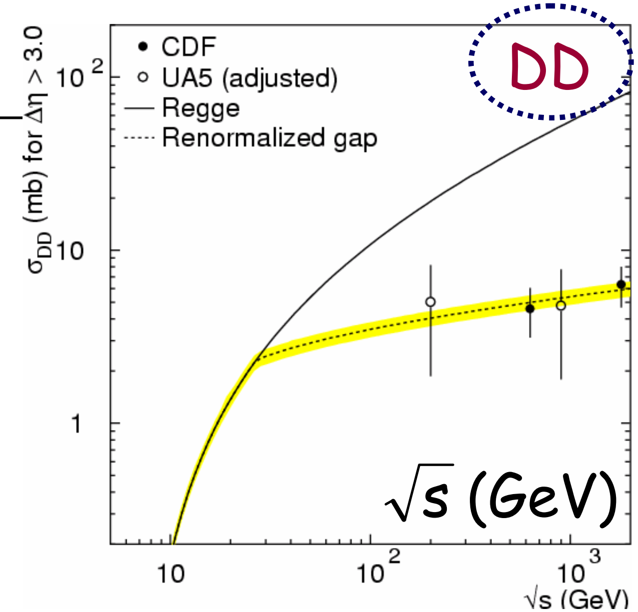
Soft Diffraction : Summary

Good Agreement with Renormalized Gap Predictions!

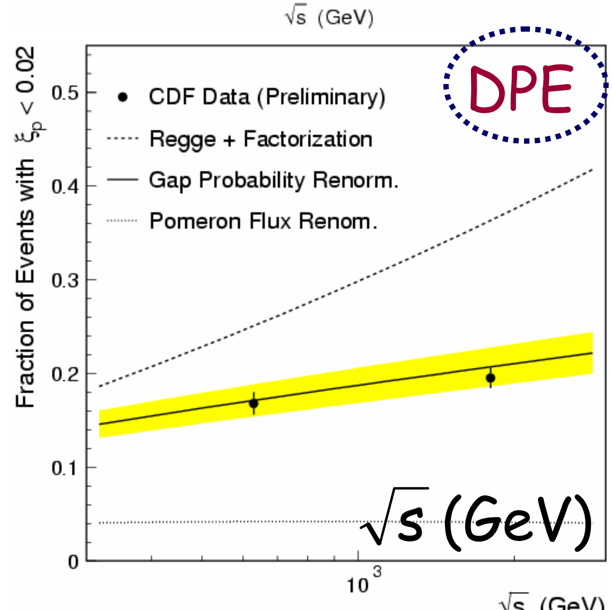


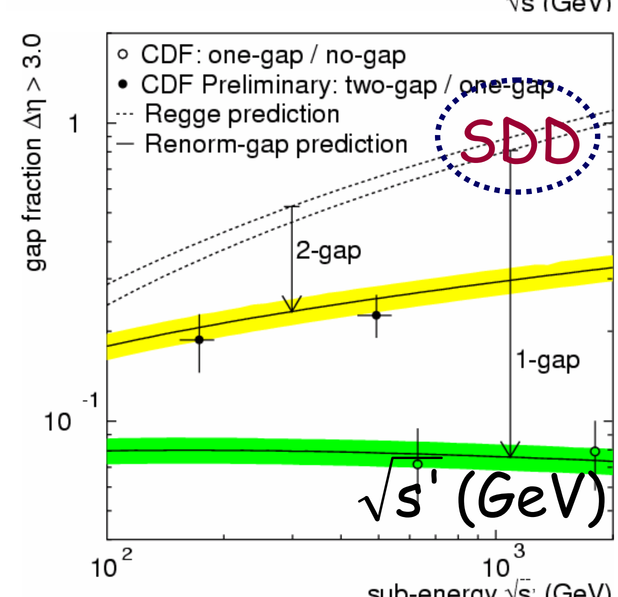
σ (mb)





Gap Fraction





Conclusions

- The measured ξ_p^X distribution exhibits $\sim 1/\xi^{1+\varepsilon}$ behavior ($\varepsilon = 0.104$).
- The measured DPE fraction in SD is :

$$R\left[\frac{DPE}{SD(incl)}\right] = 0.195 \pm 0.001(stat) \pm 0.011(syst)$$

for $0.035 < \xi_{pbar} < 0.095$ and $\xi_p < 0.02$ at $\sqrt{s} = 1800$ GeV.

- in agreement with the renormalized gap prediction.

In events with a rapidity gap,
the formation of a second gap is
"unsuppressed"!