Central Rapidity Gaps in Events with a Leading Antiproton at CDF

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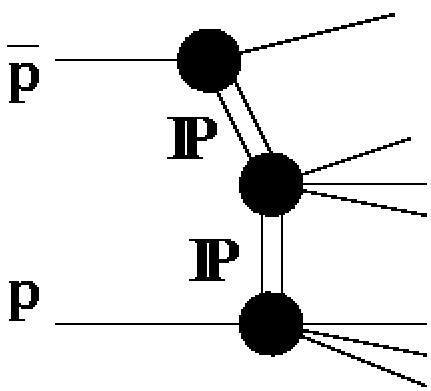
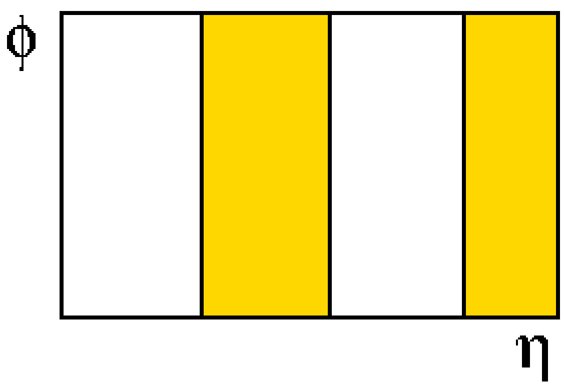
for the

CDF Collaboration

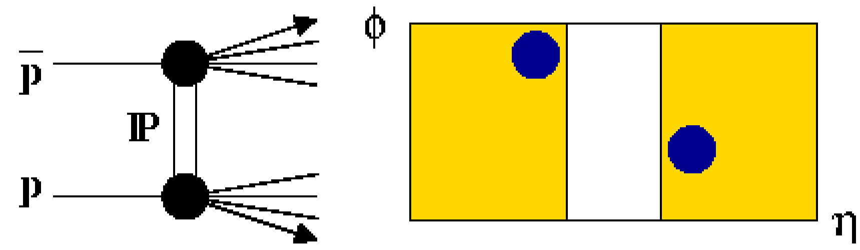




Small-x and Diffraction 2003

Introduction

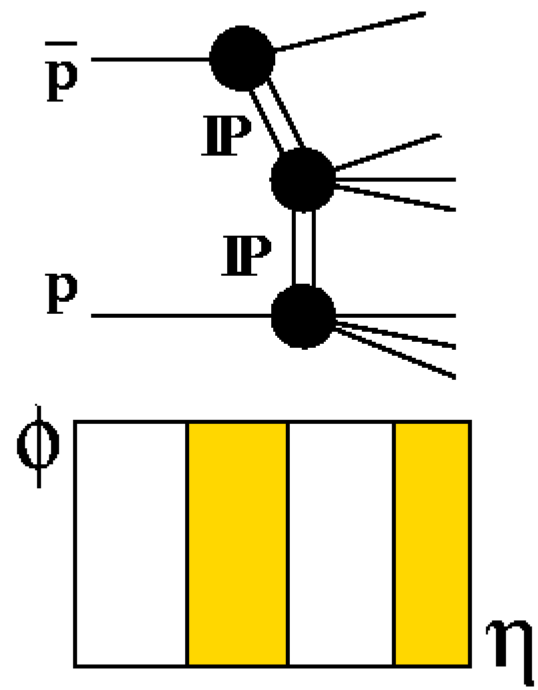
- Motivation: test QCD calculations of the Jet-Gap-Jet process
- 2 factors enter in the calculation
  - QCD (Bj 2-gluon, BFKL, ...)
  - Gap survival
- Eliminate gap survival ⇒ address QCD



- JGJ rate suppressed by
  - Jet radiation: perturbative, calculable in QCD
  - Nonperturbative effects, phenomenological models
- Determine nonperturbative experimentally

Introduction

- Measure survival probability in soft diffraction experimentally
- Multiple gaps
  - First gap survived ⇒ additional gaps also expected to survive
- Measure rate of additional (central) gaps in sample of events with a forward $\bar{p}$
  Phys. Rev. Lett. 91, 011802 (2003)

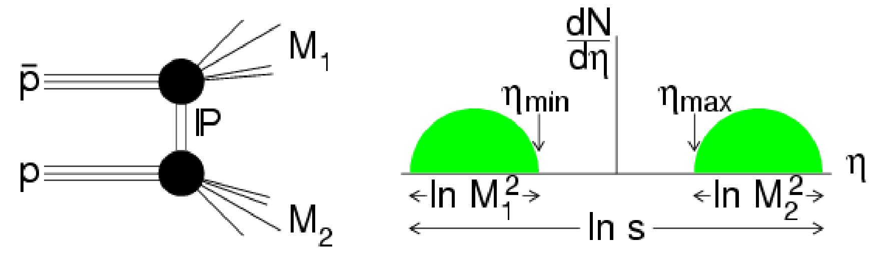


Single + Double Diffractive (SDD)

- Suppression factor $\simeq$
  double ratio (2-gap/1-gap)/(1-gap/0-gap)

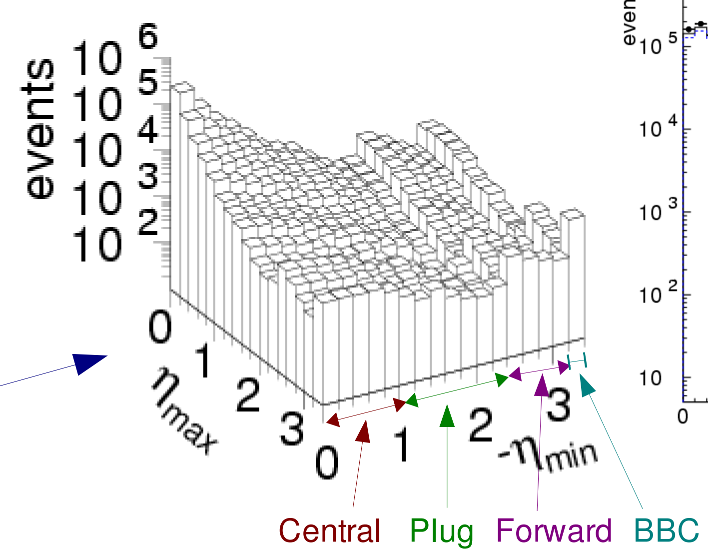
Experimental method

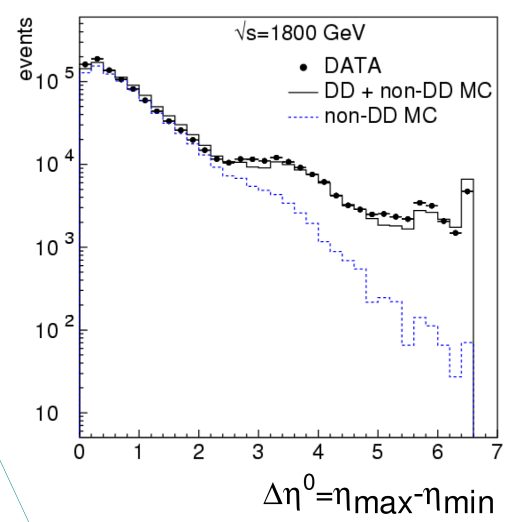
- Follow method used for DD measurement, where we looked for central gaps (overlapping η=0) in minimum-bias events



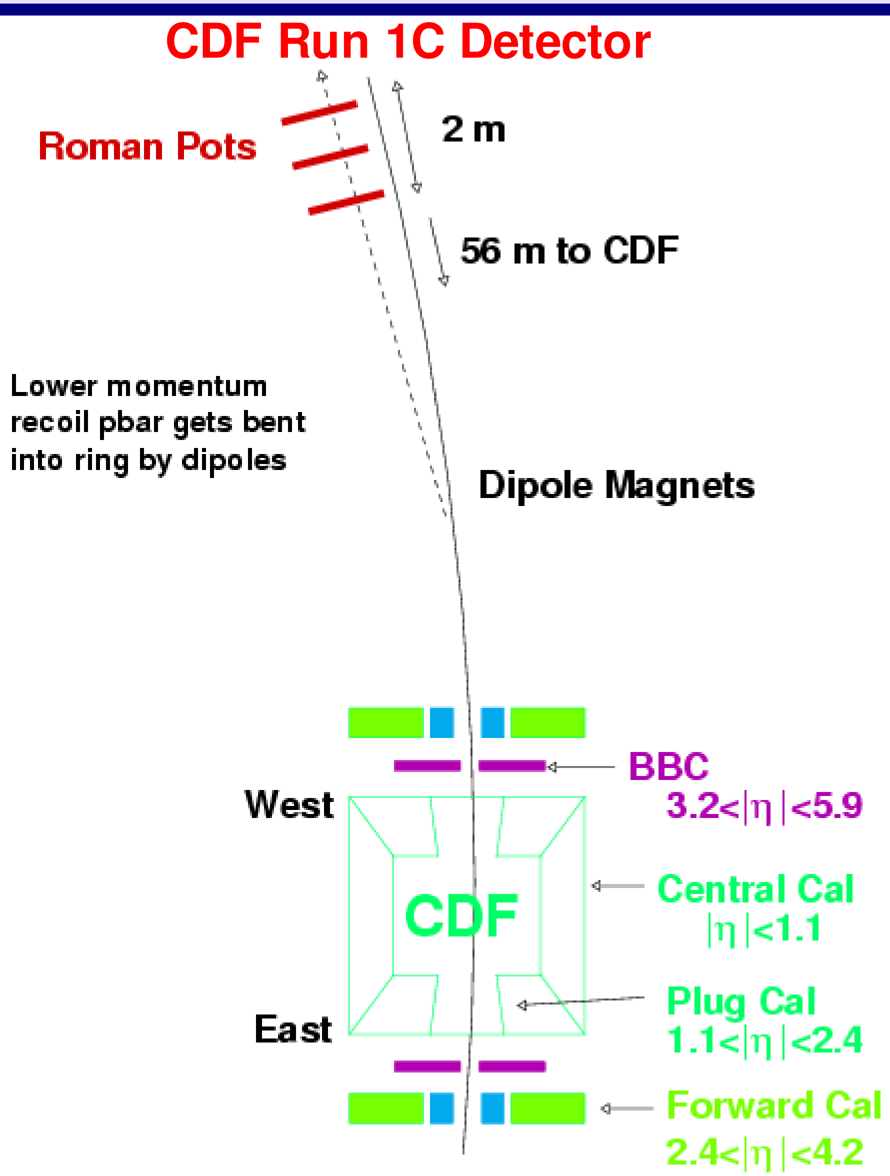
Double Diffraction

- Look for central gaps in events with a Roman-pot track (forward gap)
  - Better to look at gaps in a fixed frame because of detector effects
  - Can use MC to extrapolate to all gaps





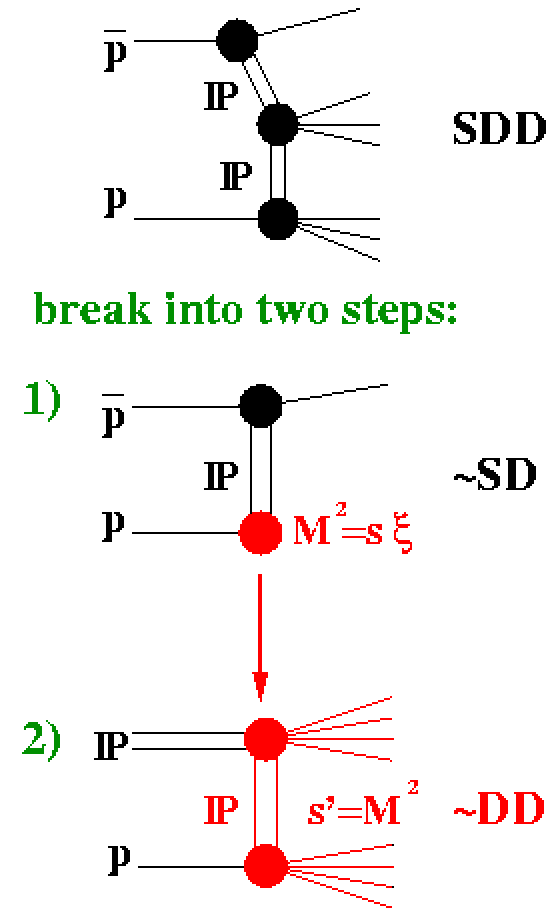
Experimental method



- 1.5M(1M) Roman-pot triggered events at $\sqrt{s}$=1800 (630) GeV from Tevatron Run 1C
- $0.06<\xi_{\bar{p}}<0.09$, $|t_{\bar{p}}|<1.0(0.2)$ GeV^2
- Require hits in the Beam-Beam Counters (BBC) on the p side to exclude DPE
- Require ≤1 reconstructed vertex to exclude multiple $\bar{p}p$ interactions

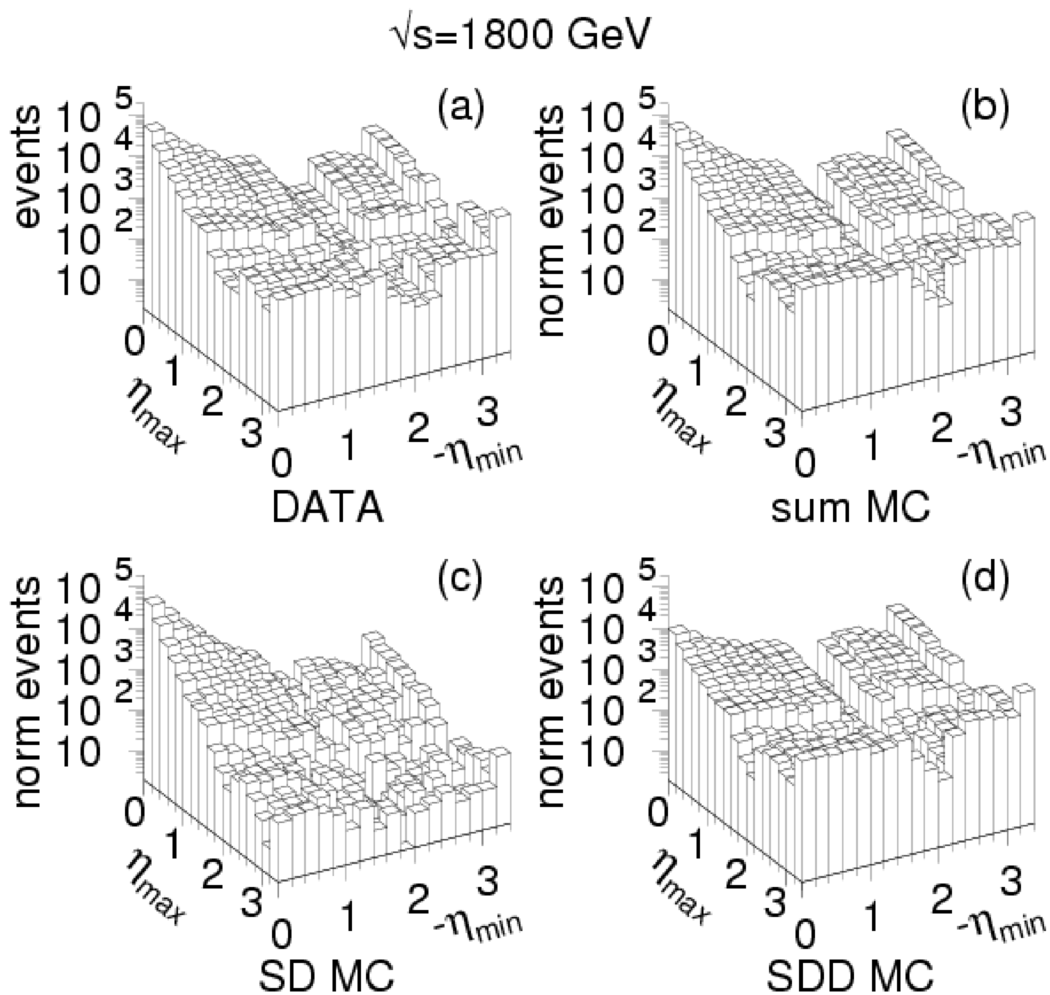
Monte Carlo simulation

- Minimum-bias event generator
  - Specifically designed to reproduce soft-interaction results from lower energy experiments
  - Differential cross sections from Regge theory
- Used to generate background (SD) events
- Modified to generate SDD

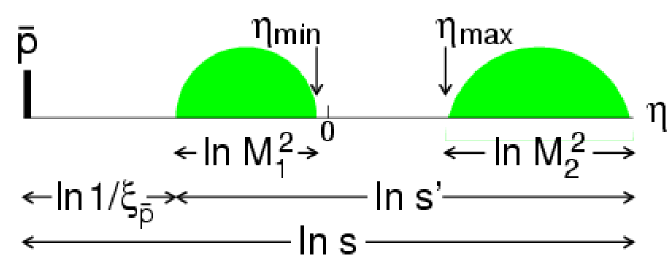


- Calorimeter response to low-p_T particles modelled as in previous diffractive analyses (η dependent)

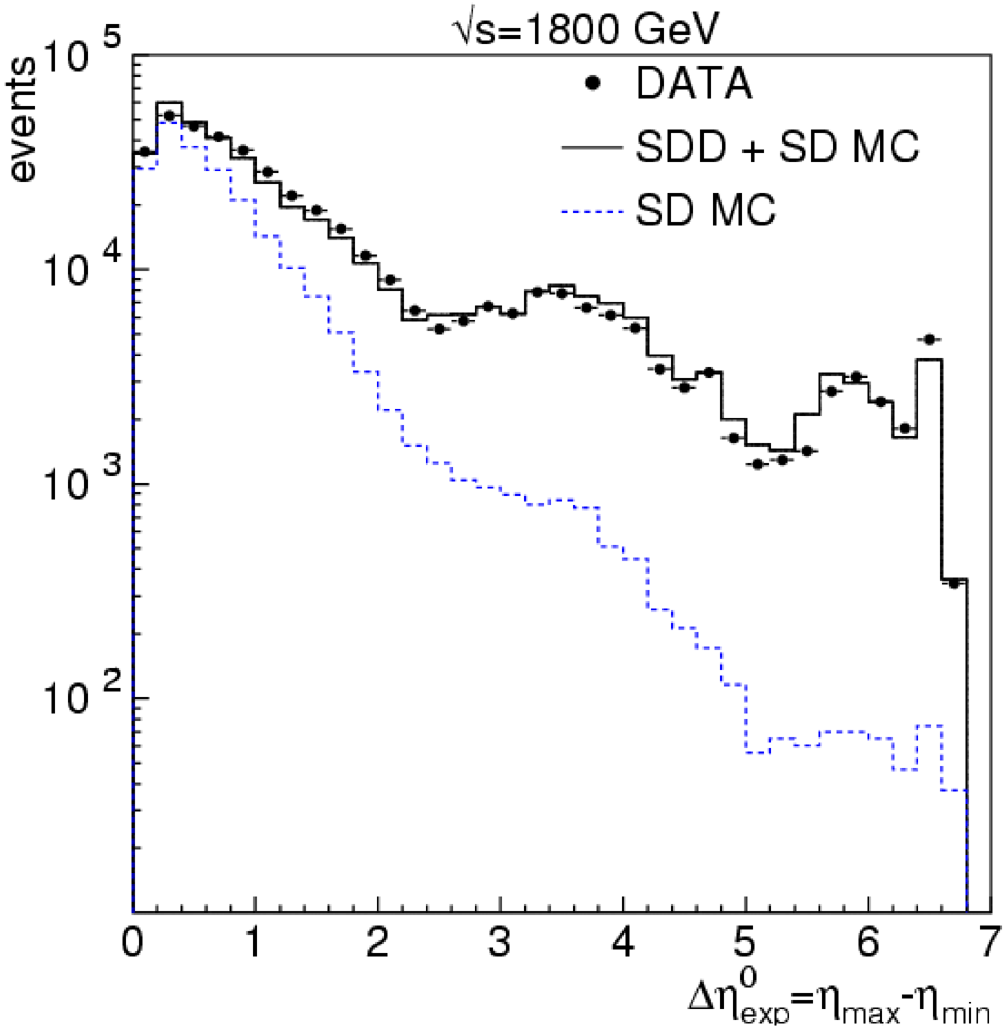
Number of events as a function of η_{max} and $-\eta_{min}$



- Note η-dependent thresholds and calorimeter regions
  ($|\eta|<1.1$ central,
  $\sim1.1<|\eta|<\sim2.4$ plug,
  $|\eta|>2.4$ forward)
- $|\eta|_{max/min}\equiv3.2$ for hits in BBC ($3.2<\eta<5.9$), $\eta_{min}\equiv-3.3$ for events with no hits on $\bar{p}$ side



Number of events as a function of $\Delta\eta^0_{exp}=\eta_{max}-\eta_{min}$



- Fit background in small $\Delta\eta^0$ region (dominantly SD) and extrapolate to $\Delta\eta^0>3$
  - Background is already small in region $\Delta\eta^0>3$
  - Cross section does not depend strongly on details of MC
- To the extent the MC does fit the shape of $\Delta\eta^0$, we can use it to calculate the acceptance for hitting the BBC and to extrapolate the fraction of events with a 2nd gap to all gaps $\Delta\eta>3$

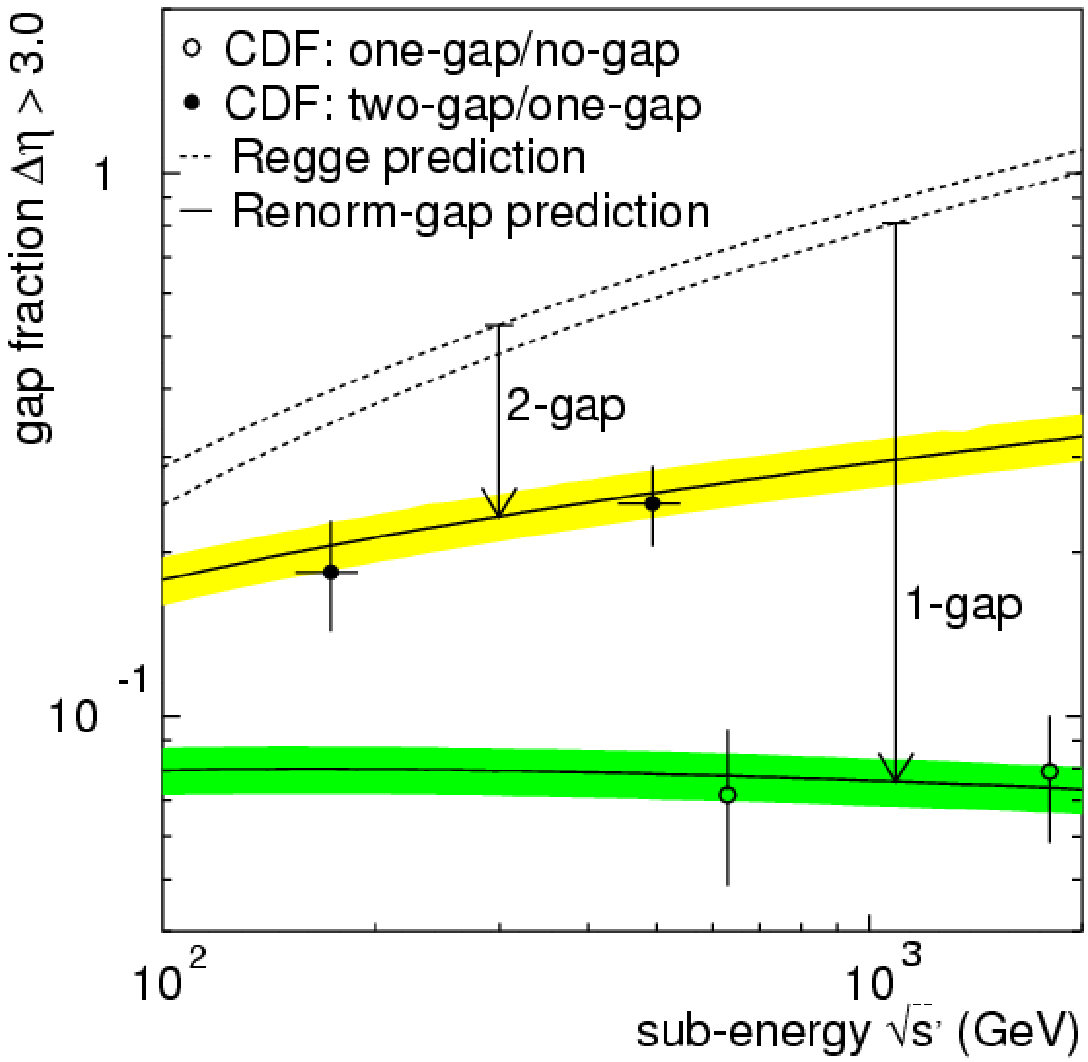
Fraction of Roman-pot triggered cross section with gap >3 at $\sqrt{s}$=1800 GeV ($\sqrt{s'}$~441-540 GeV)

- Measured fraction of events with $\Delta\eta^0_{exp}>3$
  0.159±0.001(stat)
- SD background (from SD MC) 0.012 (syst error determined by varying calorimeter E_T thresholds)
- Acceptance for p-side BBC hit (from SDD, SD MC)
  A_{SDD}=(68±6)%, A_{SD}=(98±1)%
- Correct to nominal gaps (account for particles in gap below threshold) $\Delta\eta^0_{nom} \equiv \ln(s's_0/M_1^2M_2^2)$ (from SDD MC) $\times$0.81
  $R^{nom}_{\Delta\eta^0>3}$=0.174±0.001(stat)±0.030(syst)
- Extrapolate to all gaps >3 $\times$1.44
  R=0.246±0.001(stat)±0.042(syst)

Fraction of Roman-pot triggered cross section with gap >3 at $\sqrt{s}$=630 GeV ($\sqrt{s'}$~154-189 GeV)

- Measured fraction of events with $\Delta\eta^0_{exp}>3$
  0.175±0.002(stat)
- SD background (from SD MC) 0.024 (syst error determined by varying calorimeter E_T thresholds)
- Acceptance for p-side BBC hit (from SDD, SD MC)
  $A_{SDD}=(81\pm4)\%$, $A_{SD}=(98\pm1)\%$
- Correct to nominal gaps (account for particles in gap below threshold) $\Delta\eta^0_{nom}\equiv\ln(s's_0/M_1^2M_2^2)$ (from SDD MC) $\times0.73$
  $R^{nom}_{\Delta\eta^0>3}=0.138\pm0.001(stat)\pm0.032(syst)$
- Extrapolate to all gaps >3 $\times1.40$
  R=0.184±0.001(stat)±0.043(syst)

Fraction of events with a gap



- Find ≃20% of ($I\!\!P p$) interactions in events with a leading $\bar{p}$ have an additional rapidity gap $\Delta\eta>3$
- In comparison, ≃8% of inelastic NSD ($\bar{p}p$) interactions have a gap $\Delta\eta>3$
  - ➔ Once one gap is produced, additional gaps are easier to produce

Renormalized gap prediction

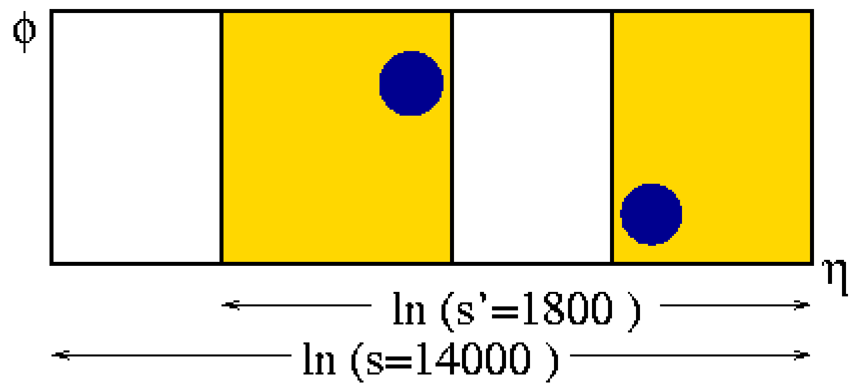
- See "Diffraction in QCD", K. Goulianos, Presented at Corfu Summer Institute on Elementary Particle Physics, Corfu, Greece, 31 Aug - 20 Sep 2001, hep-ph/0203141.

Gap probability – norm to 1

- SD: $d^2\sigma/d\Delta y'dt \quad = CF_p{}^2(t)e^{2(\varepsilon+\alpha' t)\Delta y} \times \kappa\, \sigma_0 e^{\varepsilon\Delta y'}$
- SDD: $d^5\sigma/d\Delta y'dt\ldots = CF_p{}^2(t)\prod_{i=1,2} e^{2(\varepsilon+\alpha' t_i)\Delta y_i} \times \kappa^2 \sigma_0 e^{\varepsilon(\Delta y'_1+\Delta y'_2)}$
- $\Rightarrow$ SDD/SD ~ $\kappa = g(t)/\beta(0) \simeq g(0)/\beta(0) = 0.17\pm0.02$
- We find (SDD/SD) $\simeq$ 0.2
- Ratio (1-gap/0-gap)/(2-gap/1-gap) also predicted (~survival probability)
- We find (DD/ND)/(SDD/SD) $\simeq$ 0.08/0.2 = 40%

Conclusions

- Multiple gaps can be used to eliminate gap survival from QCD calculations



  - Production of additional gaps should not be suppressed by gap survival probability
  - (2-gap/1-gap)~κ

- Multiple gaps can also be used to measure the gap survival probability
  - (1-gap/0-gap)/(2-gap/1-gap) ~ 40%