Photoproduction of Events with Rapidity Gaps Between Jets at ZEUS

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On Behalf of the ZEUS Collaboration

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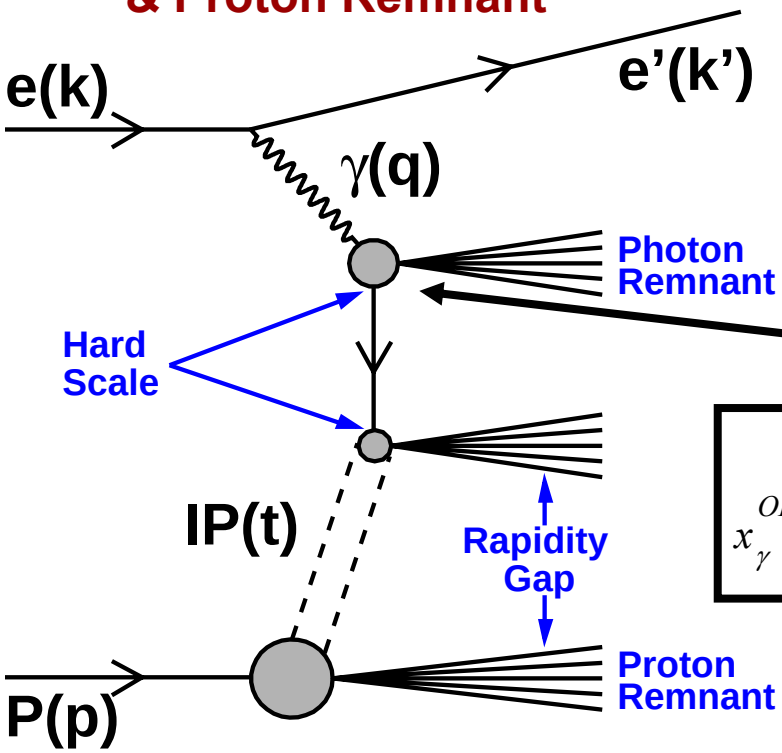
Results Presented at DIS 2006

Hard Diffractive Photoproduction

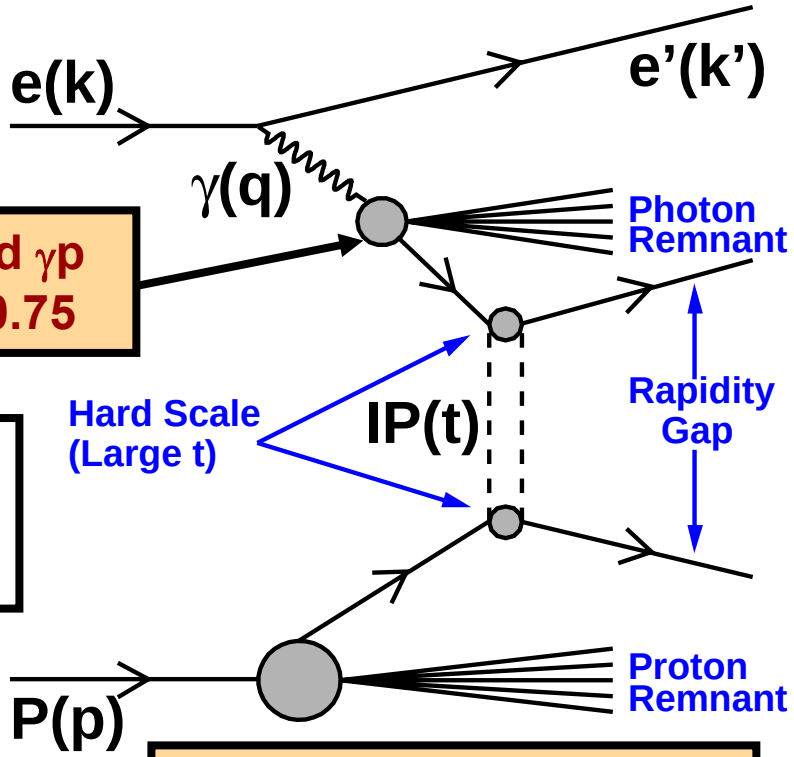
Rapidity Gap Between Hadron & Proton Remnant



Resolved γp
$x_\gamma^{OBS} < 0.75$

$$x_\gamma^{OBS} = \frac{\sum_{jets} E_T e^{-\eta}}{2yE_e}$$

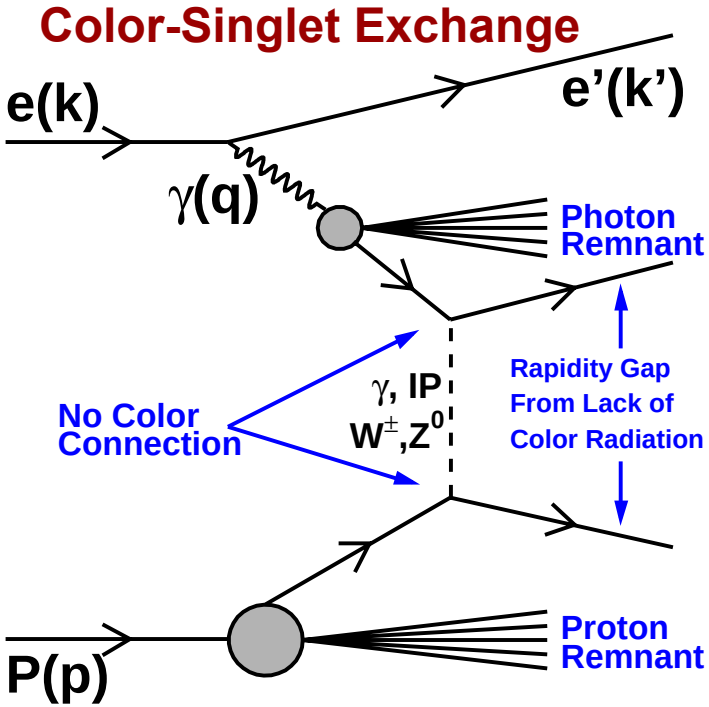
Rapidity Gap Between Jets

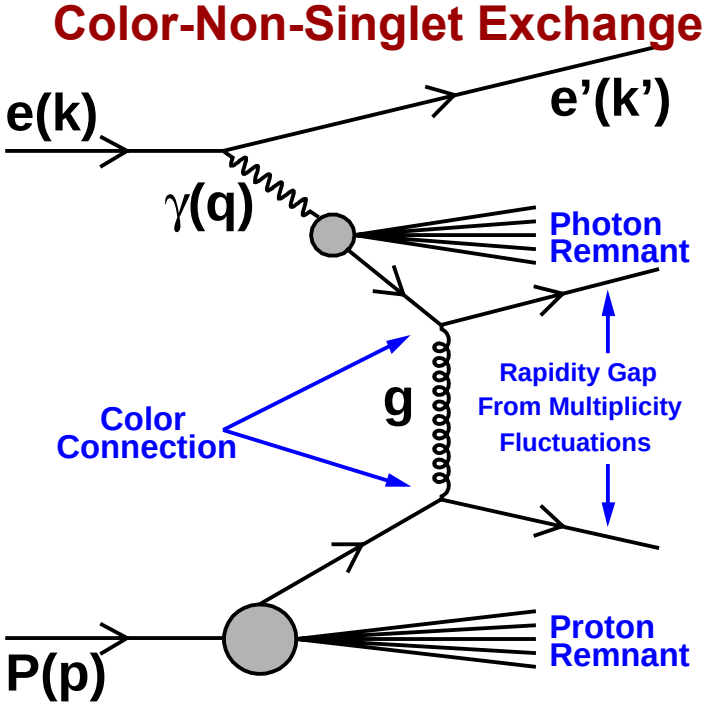


Subject of this analysis

- Study the nature of the Pomeron
  - Observe Color-Singlet exchange
- Hard Scale allows application of pQCD to diffractive process

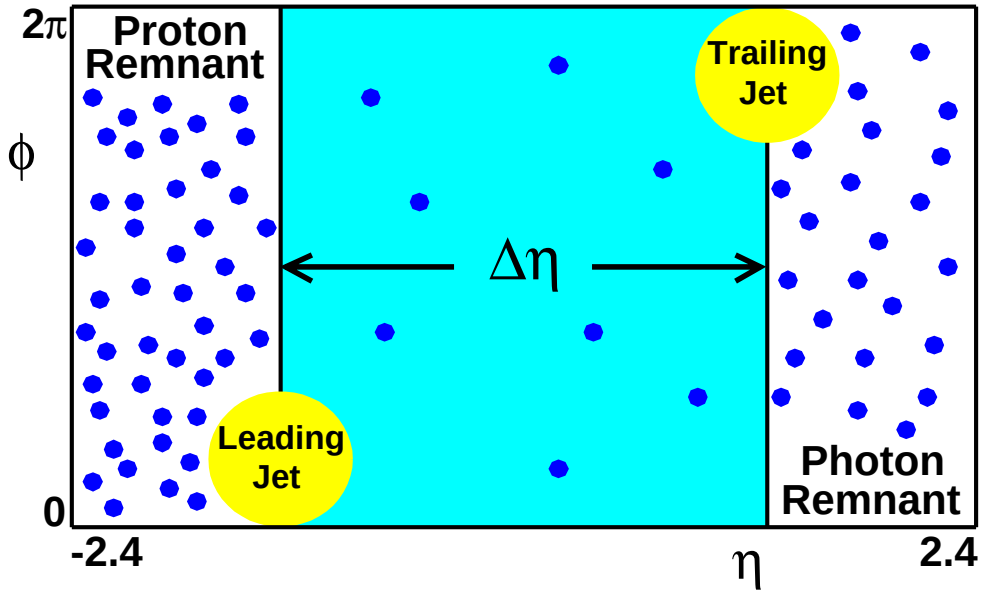
Rapidity Gaps between Jets





- **2 Sources of Rapidity Gaps between Jets**
  - **Color-singlet Exchange**
    - Lack of color radiation produces gap
    - Example: Pomeron
  - **Color-Non-Singet Exchange**
    - Fluctuations in particle multiplicity produces gap
    - Non-diffractive

Rapidity Gap Topology



- Distance between leading and trailing jet centers: $\Delta\eta$
- E_T^{Gap}: Total E_T of jets between leading and trailing jet centers
- Gap Event has small energy in Gap: $E_T^{Gap} < E_T^{Cut}$
- Gap definition based on E_T better than that based on multiplicity
  - Collinear and infrared safe
  - Gap spans between centers of leading & trailing jets (increased statistics)

The Gap Fraction f(Δη)

Dijet Events with large Rapidity separation between jets & $E_T^{Gap} < E_T^{Cut}$

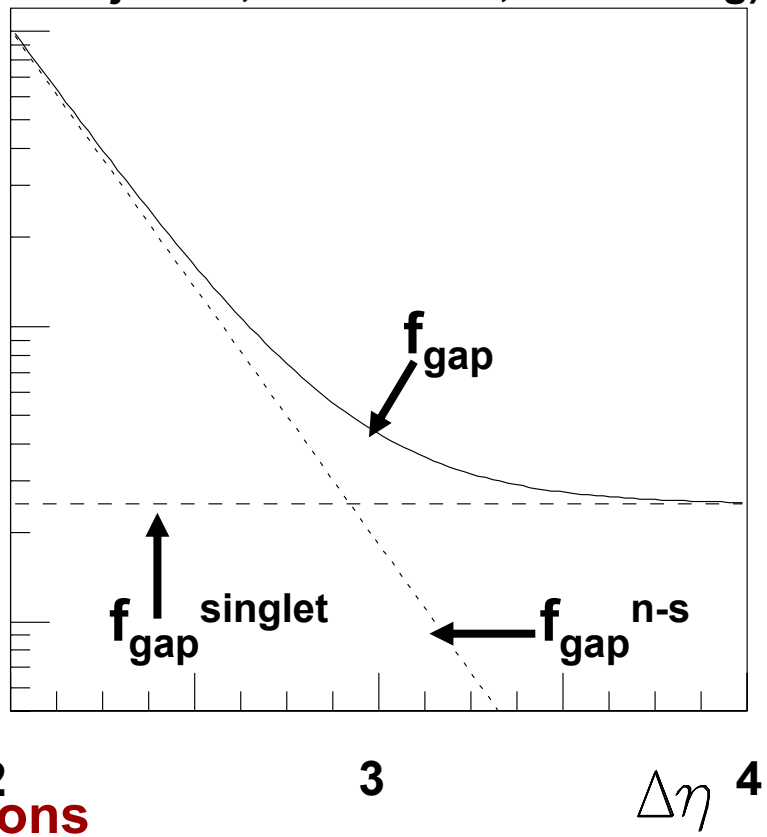
$$f(\Delta\eta) = \frac{d\sigma_{gap}/d\Delta\eta}{d\sigma/d\Delta\eta}$$

All Dijet Events with large Rapidity separation between jets

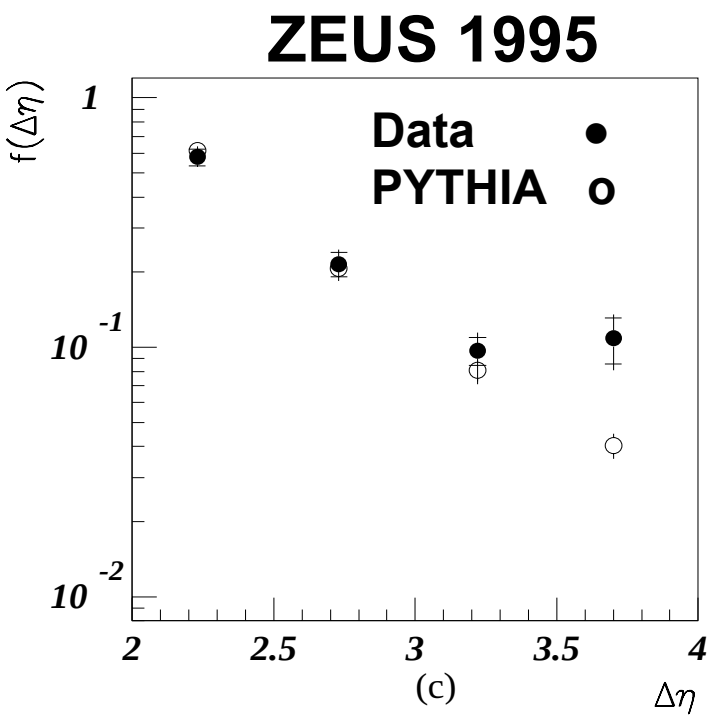
$$\sigma_{gap} = \sigma_{gap}^{singlet} + \sigma_{gap}^{non-singlet}$$

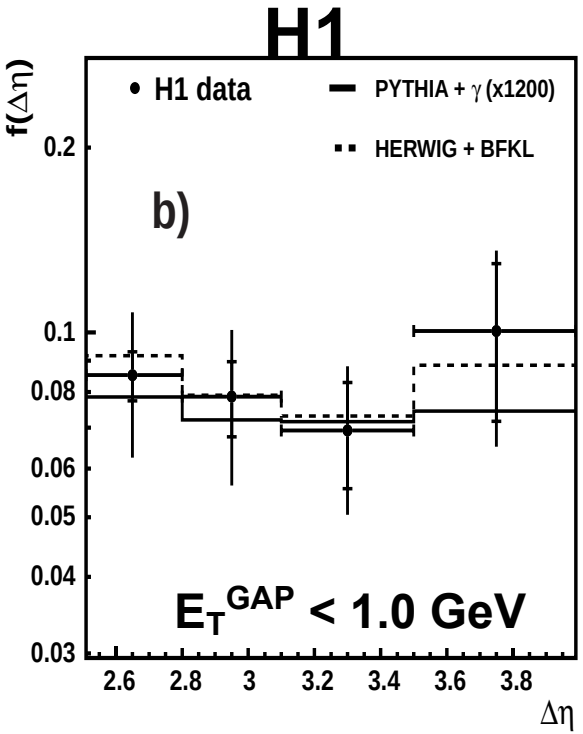
- **Color Singlet**
  - Gap created by lack of color flow
  - f(Δη) constant in Δη
- **Color Non-Singlet**
  - Gap created by multiplicity fluctuations
  - f(Δη) decreases exponentially with Δη

Expectation for Behavior of Gap Fraction (J. D. Bjorken, V. Del Duca, W.-K. Tung)



Comparison to Previous ZEUS and H1 Measurements





- **ZEUS 1995: Gap Fraction defined by multiplicity**
  - **Data above Non-Color-Singlet PYTHIA**
- **H1 2002: Gap Fraction for $E_T^{Gap} < 1.0$ GeV**
  - **Data above NCS MC but Data described by NCS+CS MC**
  - **6.6 pb^{-1} of Lumi**

Simulation of Color-Non-Singlet and Color-Singlet MC

- **PYTHIA 6.1 & HERWIG 6.1**
  - **Used to simulate Color-Non-Singlet and Color-Singlet Events**
  - **Shown to describe γp data**
  - **Use different hadronization models**
  - **Direct, Resolved, Color-Singlet MC generated separately**
- **Color-Non-Singlet MC**
  - **Resolved MC includes Multi-Parton Interactions (MPIs)**
- **Color-Singlet (CS) Exchange MC**
  - **HERWIG: BFKL Pomeron as exchange object**
    - Includes MPIs
  - **PYTHIA: High-t γ exchange**
    - Used to match data only – Rapidity Gap not due to photon exchage
    - Does not include MPIs

Monte Carlo Tuning

- **Modified Default ZEUS MC parameters**
  - Tuning based on JetWeb parameters (Global fit to collider data)
  - Tuned p_T^{Min} to ZEUS E_T^{GAP} distributions (shown later)
- **Tuned PYTHIA 6.1**
  - Proton PDF: CTEQ 5L (Set 46)
  - Photon PDF: SaS-G 2D
  - $p_T^{Min\ 1}$= 1.9 $p_T^{Min\ 2}$= 1.7 (default 2.0 GeV, 1.5 GeV)
- **Tuned HERWIG 6.1**
  - Proton PDF: CTEQ 5L (Set 46)
  - Photon PDF SaS-G 2D
  - Square of factor to reduce proton radius: 3.0 (default 1.0)
  - Probability of Soft Underlying Event: 0.03 (default 1.0)
  - P_T^{MIN1} = 2.7 GeV (default 1.8 GeV)

$p_T^{Min\ 1}$: p_T of hardest interaction

$p_T^{Min\ 2}$: p_T of all secondary interactions

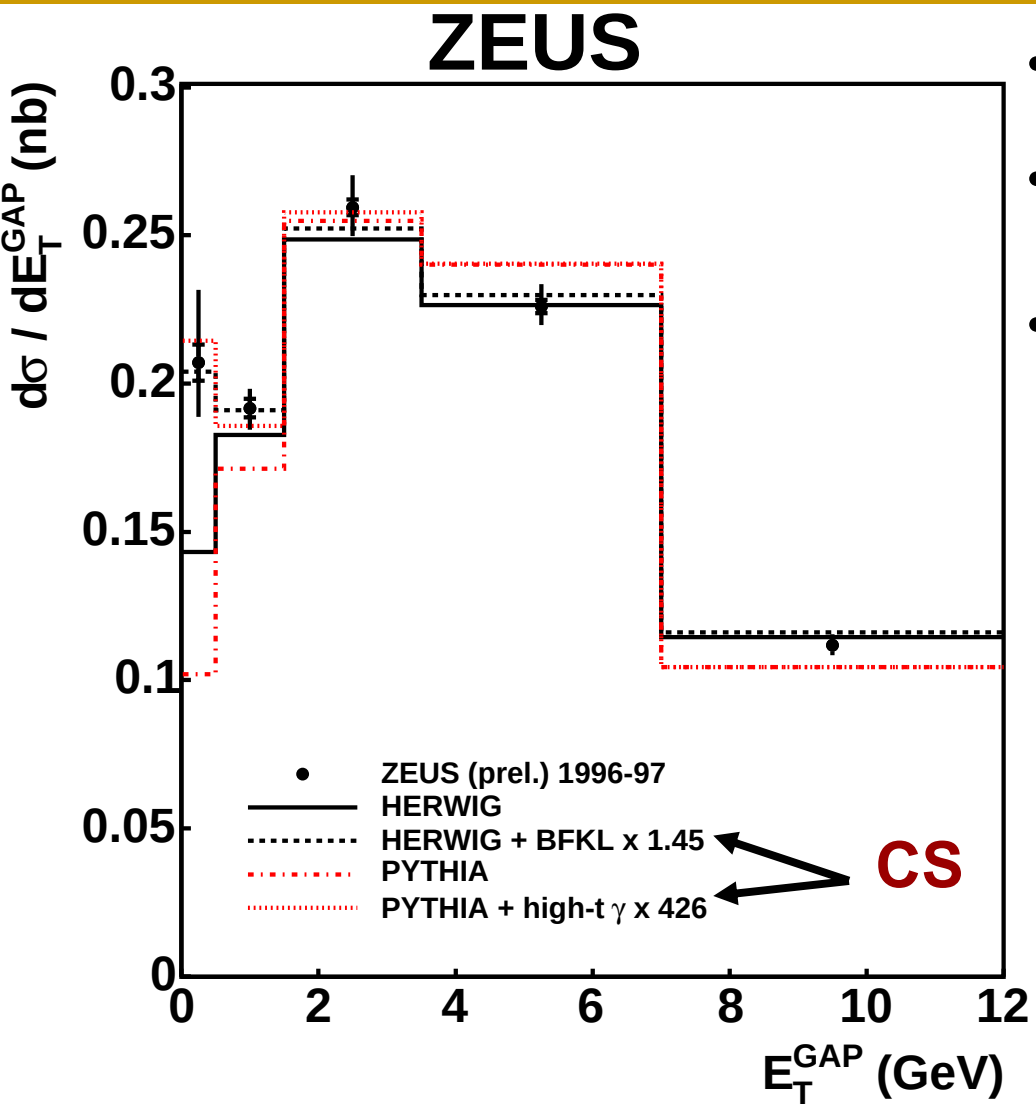
Data Acceptance Corrections

- **Correct data for acceptance: Detector → Hadron level**
- **Step 1: Dir and Res relative amounts fit to Data: x_γ^{OBS} distribution**
  - **PYTHIA – Detector Level**
    - 28% Direct
    - 72% Resolved
  - **HERWIG – Detector Level**
    - 44% Direct
    - 56% Resolved
- **Step 2: Non-Color Singlet & Color Singlet relative amounts fit to Data: E_{TOT} for $E_T^{GAP} < 1.5$ GeV**

Rapidity Gap Event Selection

ZEUS 1996-97 Data (38 pb^{-1})	
Trigger Selection:	
FLT, SLT, and TLT requirements to select dijet photoproduction events	
Clean Photoproduction Sample:	
Reject events having Electron with $E_e > 5$ GeV **AND** $y_e < 0.85$	
$\Sigma p_T / \Sigma\sqrt{E_T} < 2$ $GeV^{1/2}$	
$\lvert z_{vtx}\rvert < 40$ cm	$0.2 < y_{JB} < 0.85$
Dijets with Large Rapidity Separation:	
$E_T^{1,2} > 6.0, 5.0$ GeV	
$\lvert\eta^{1,2}\rvert < 2.4$	$\frac{1}{2}\lvert\eta^1 + \eta^2\rvert < 0.75$
$2.5 < \lvert\eta^1 - \eta^2\rvert < 4.0$ **(Gap Definition)**	
4 Samples of Gap Events:	
$E_T^{CUT} = 0.5, 1.0, 1.5, 2.0$ GeV	
~70,000 Events in Inclusive Sample	

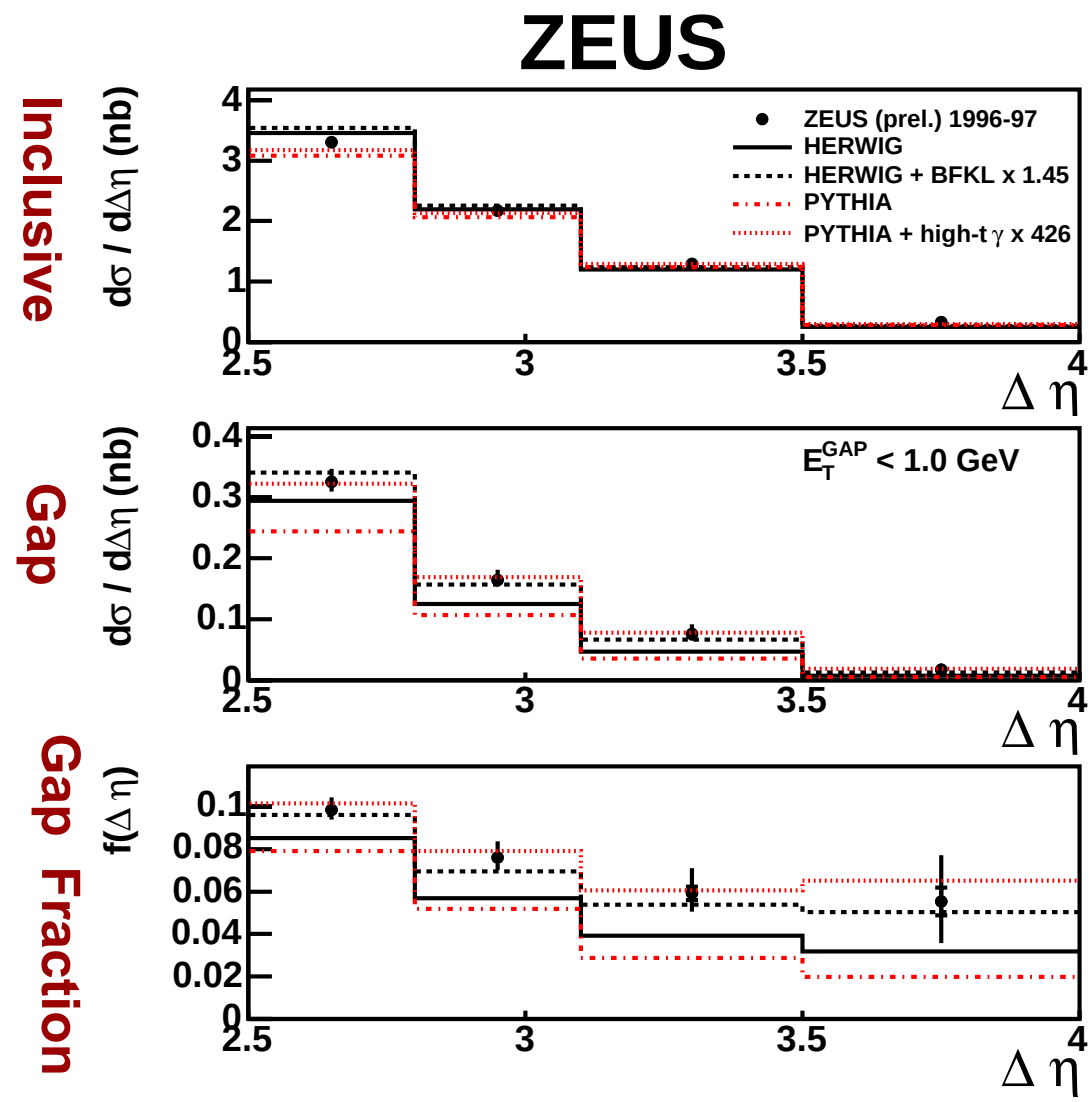
Acceptance Corrected Data vs MC E_T^{Gap} Cross Section



- Acceptance Correction
  - Average of PYT & HER
- Systematic Errors from HER
  - Difference between HER & PYT values added to systematic
- MCs fit to Data
  - χ^2 Minimization
  - Yield Scale Factors
    - HER: 1.01*NCS + 1.45*CS
    - PYT: 1.25*NCS + 426*CS
  - High CS Scale Factor in PYTHIA due to High-t γ exchange

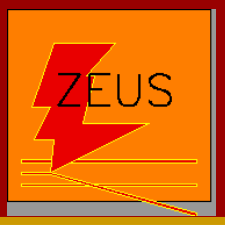
Minimization of χ^2 in fit to Data results in ~3% CS contribution for both PYTHIA & HERWIG

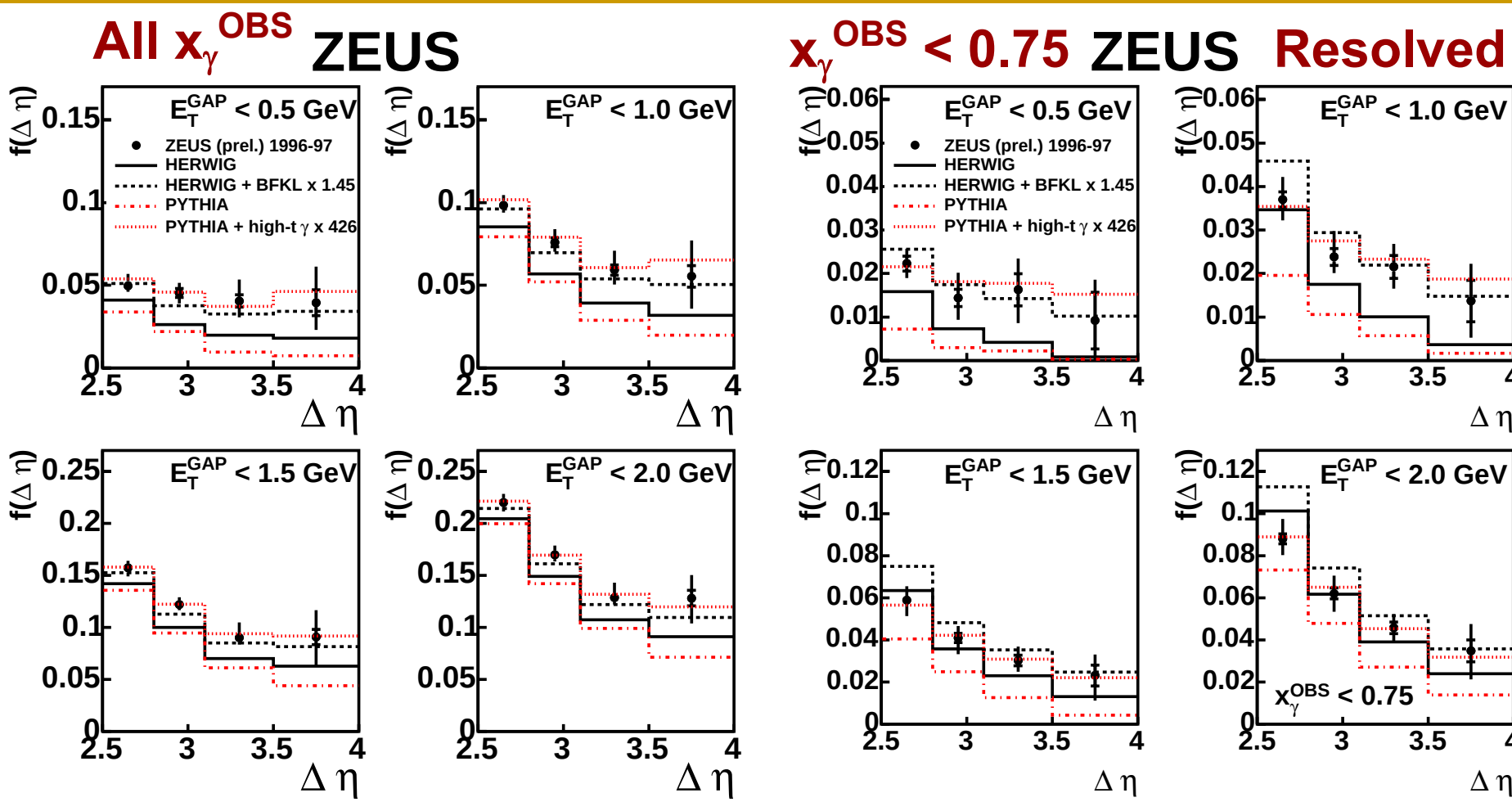
Acceptance Corrected Data vs MC
$\Delta\eta$ Cross Sections



- **MC with CS added describes data**

Acceptance Corrected Data vs MC $\Delta\eta$ for Different Gap Fractions



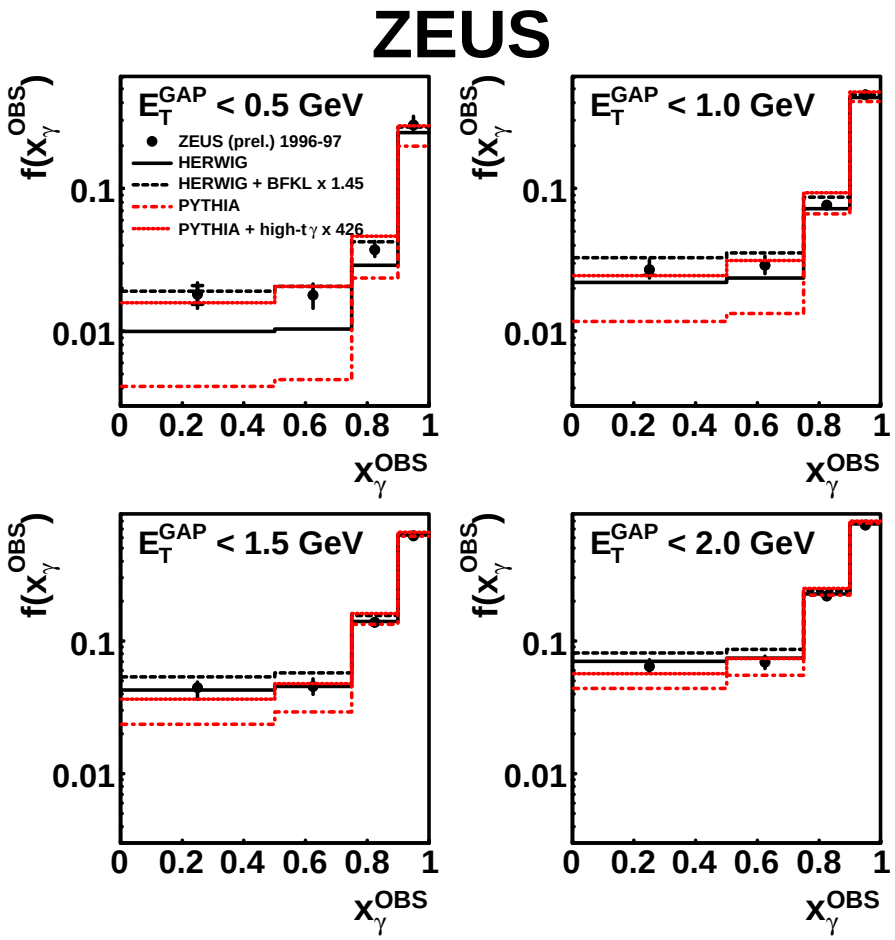


- MC with CS describes data for entire x_γ^{OBS} region
- CS contribution in resolved region is 1-2%

Acceptance Corrected Data vs MC x_γ^{OBS} for Different Gap Fractions

$$x_\gamma^{OBS} = \frac{\sum_{jets} E_T e^{-\eta}}{2yE_e}$$

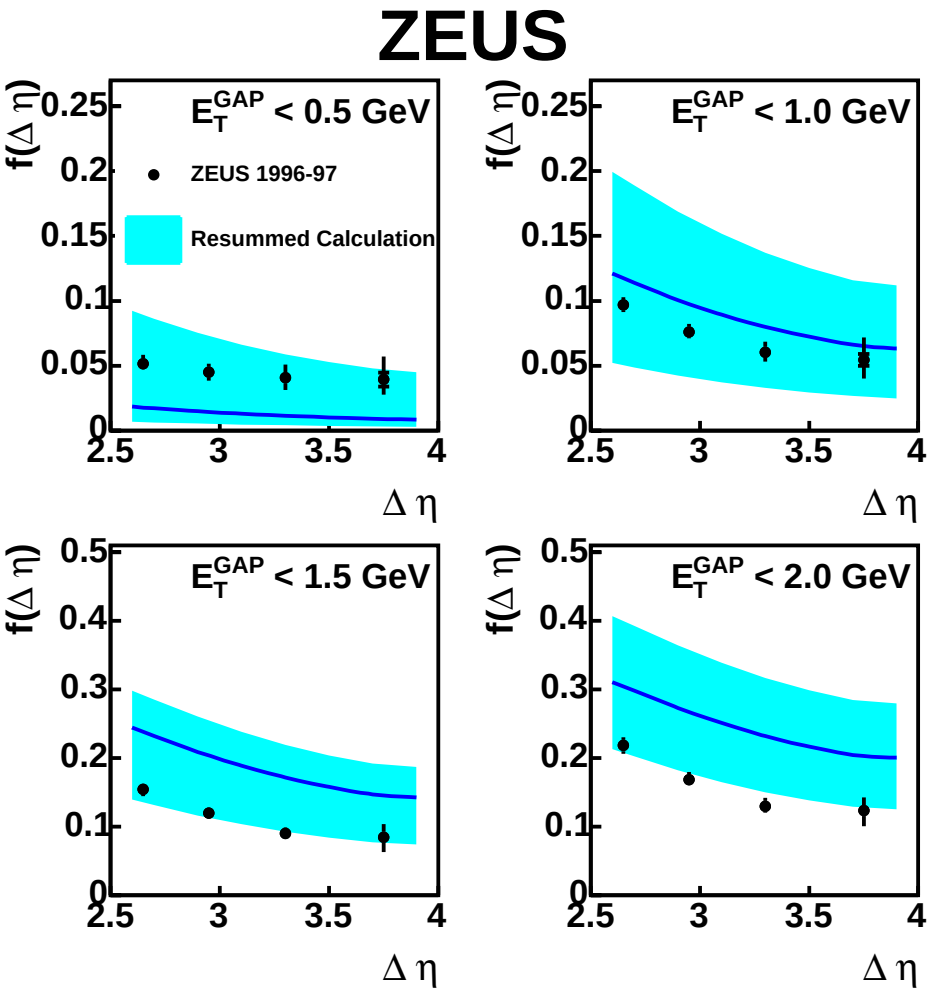
Resolved region: $x_\gamma^{OBS} < 0.75$



- MC with CS describes the Data
- HERWIG agreement remains better than PYTHIA agreement
- PYTHIA agreement in resolved region improved compared to $\Delta\eta$

Δη Gap Fractions Resummed Calculation

- **Resummed Calculation**
  - **Seymour & Appleby**
  - **Only calculation available**
  - **Large Errors**
- **Shape of data described**
  - **$E_T^{Cut} = 0.5$**
    - Data above prediction
  - **All other E_T^{Cut} values**
    - Data below predictions
    - Disagreement increases as E_T^{Cut} increases



Rapidity Gap Between Jets Summary

- **Conclusions**
  - **Data demonstrate evidence of ~3% Color-Singlet contribution estimated at the cross section level for entire phase space**
    - Corresponds to ~1-2% Color-Singlet in resolved region
  - **Data consistent with published ZEUS and H1 results**
  - **PYTHIA and HERWIG describe data well after the Color-Singlet contribution is added**
- **In Progress**
  - **Examine W dependence**
  - **Explore comparisons with Tevatron**
  - **Publish paper**