Photoproduction of Events with Rapidity Gaps Between Jets at ZEUS

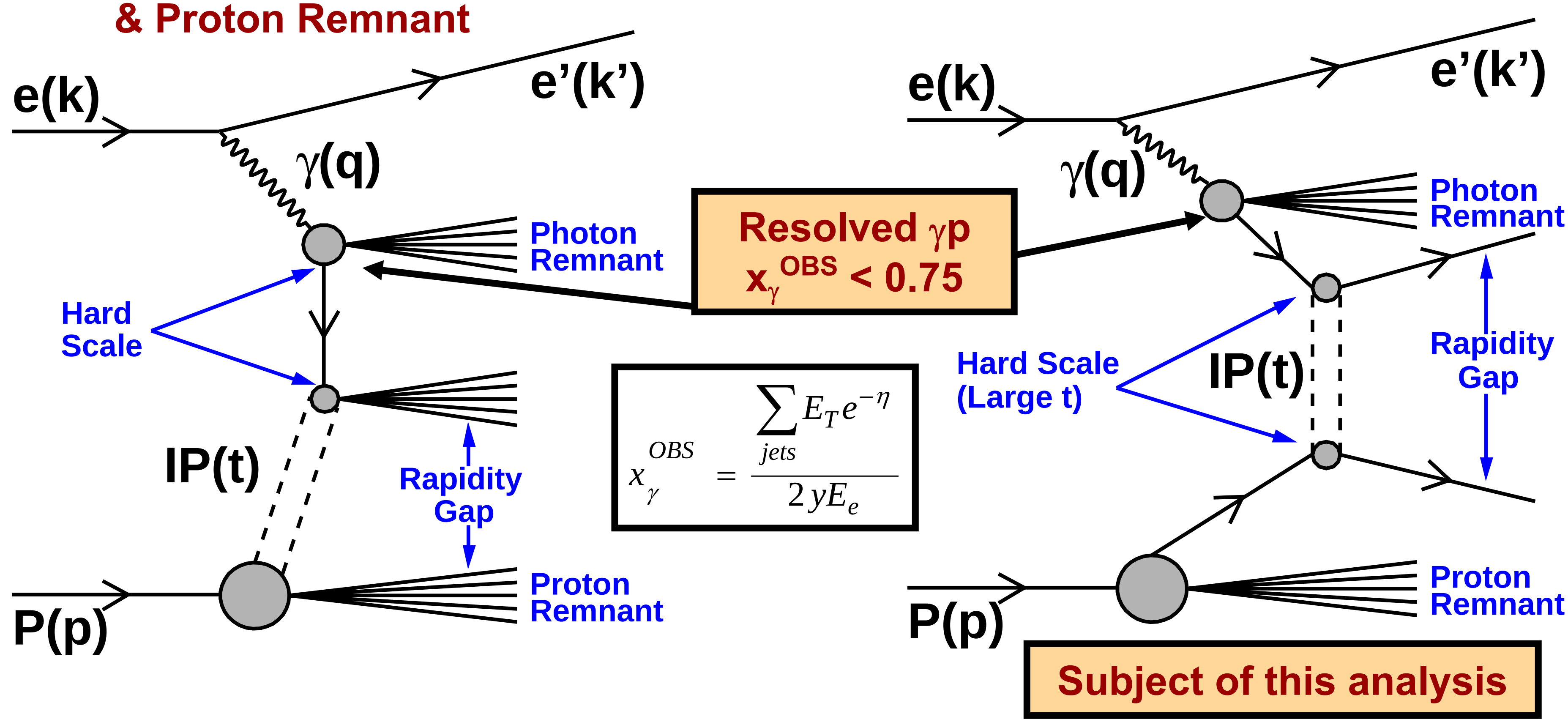
Patrick Ryan
University of Wisconsin

On Behalf of the ZEUS Collaboration

DIS 2006
Tsukuba, Japan
April 22, 2006

Hard Diffractive Photoproduction

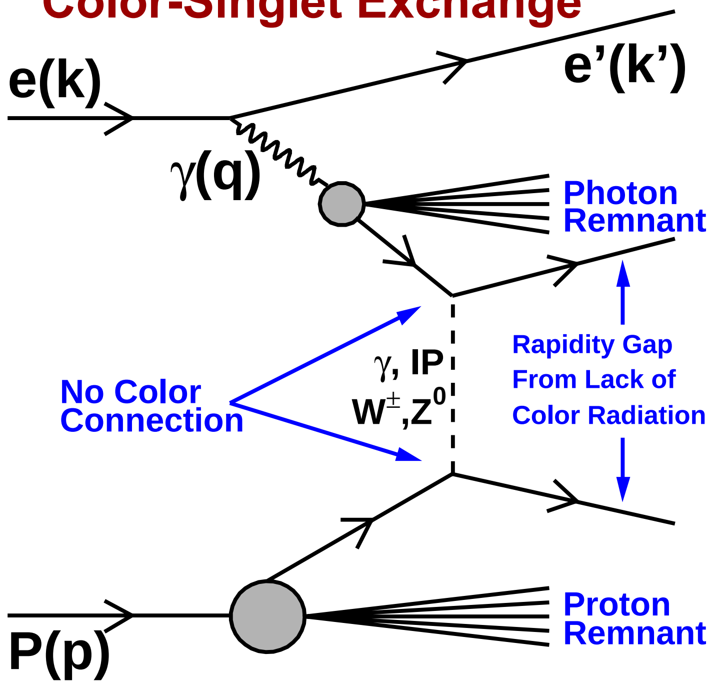
Rapidity Gap Between Hadron & Proton Remnant — **Rapidity Gap Between Jets**



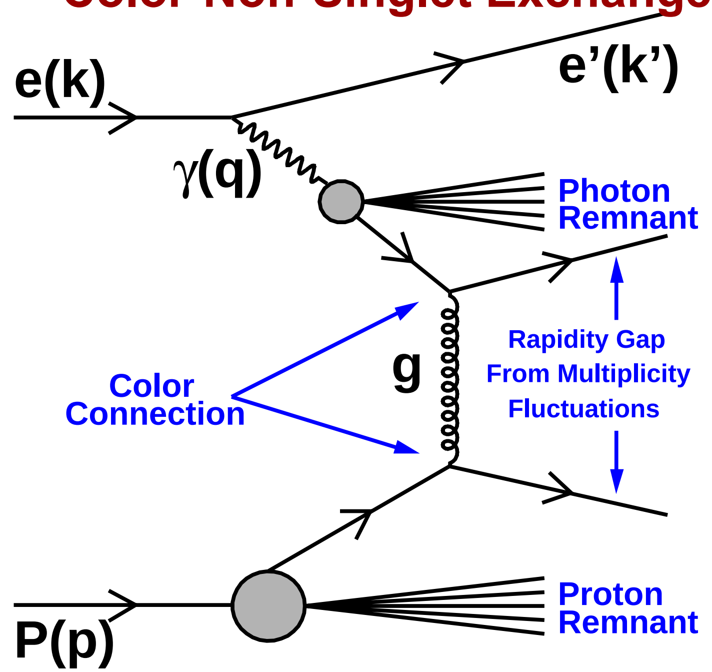
- **Study the nature of the Pomeron**
  - Observe Color-Singlet exchange
- **Hard Scale allows application of pQCD to diffractive process**

Rapidity Gaps between Jets

Color-Singlet Exchange

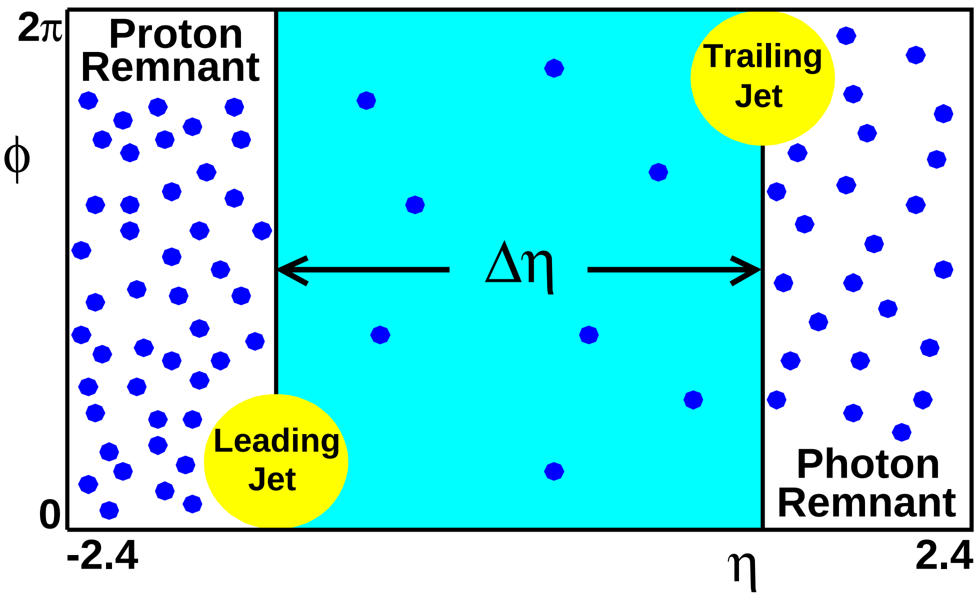


Color-Non-Singlet Exchange



- **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 & $E_T^{Gap} < E_T^{Cut}$

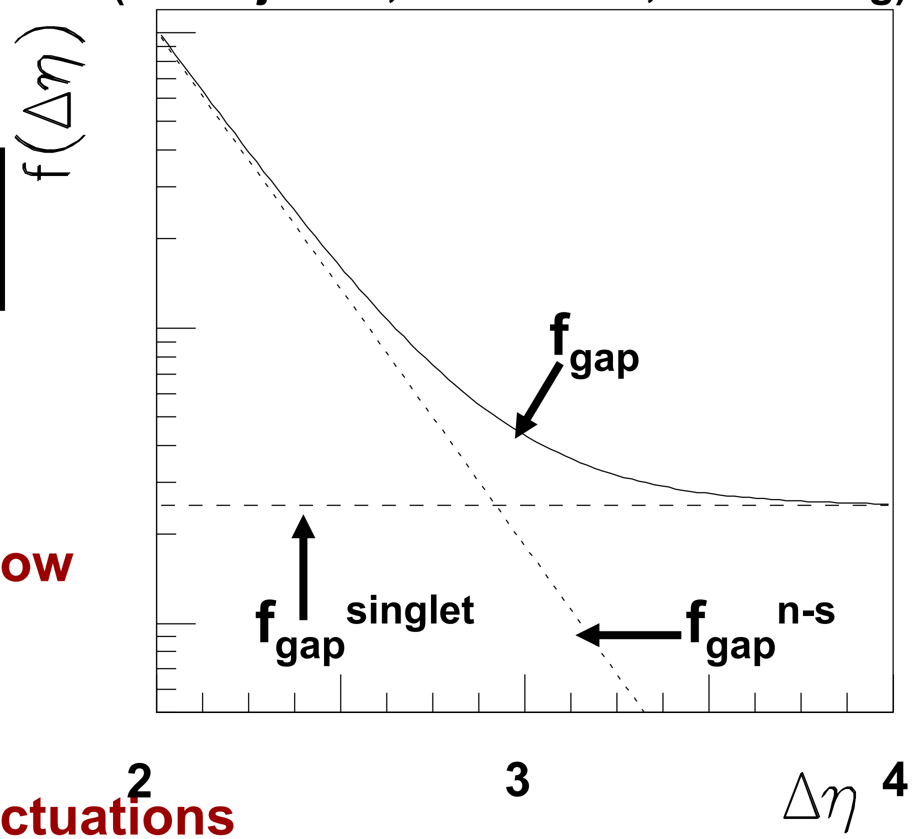
$$f(\Delta\eta) = \frac{d\sigma_{gap} / d\Delta\eta}{d\sigma / d\Delta\eta}$$

All Dijet Events with large Rapidity separation between jets

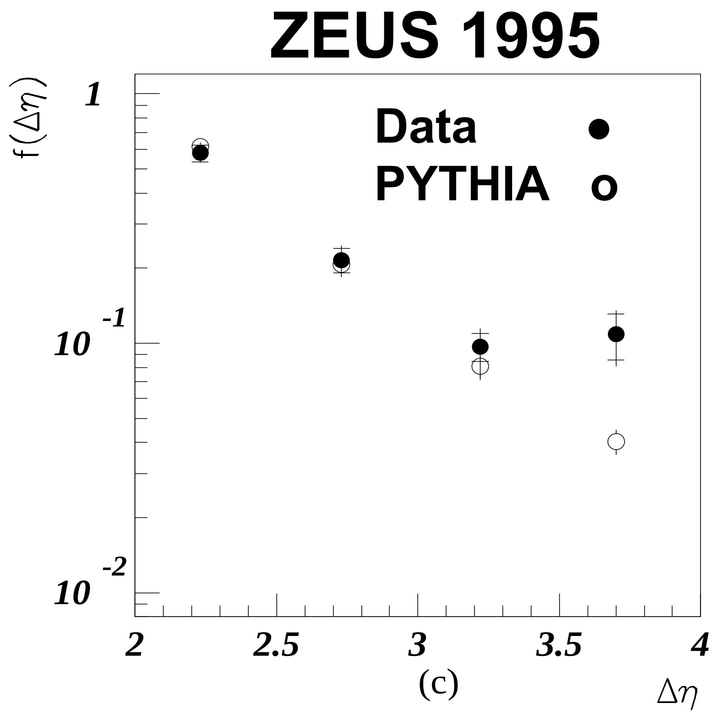
$$\sigma_{gap} = \sigma_{gap}^{\text{singlet}} + \sigma_{gap}^{\text{non-singlet}}$$

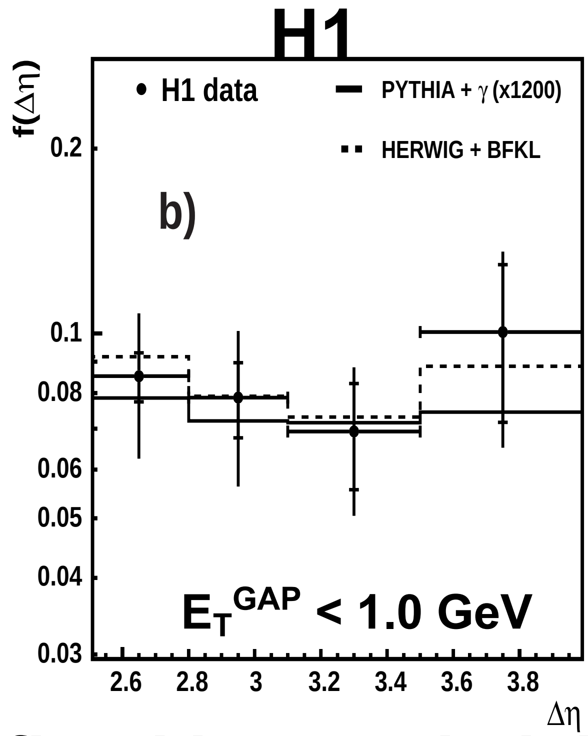
- **Color Singlet**
  - **Gap created by lack of color flow**
  - **f(Δη) constant in Δη**
- **Color Non-Singlet**
  - **Gap created by multiplicity fluctuations**
  - **f(Δη) decreases exponentially with Δη**

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)

> $p_T^{Min\ 1}$: p_T of hardest interaction
>
> $p_T^{Min\ 2}$: p_T of all secondary interactions

- **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)

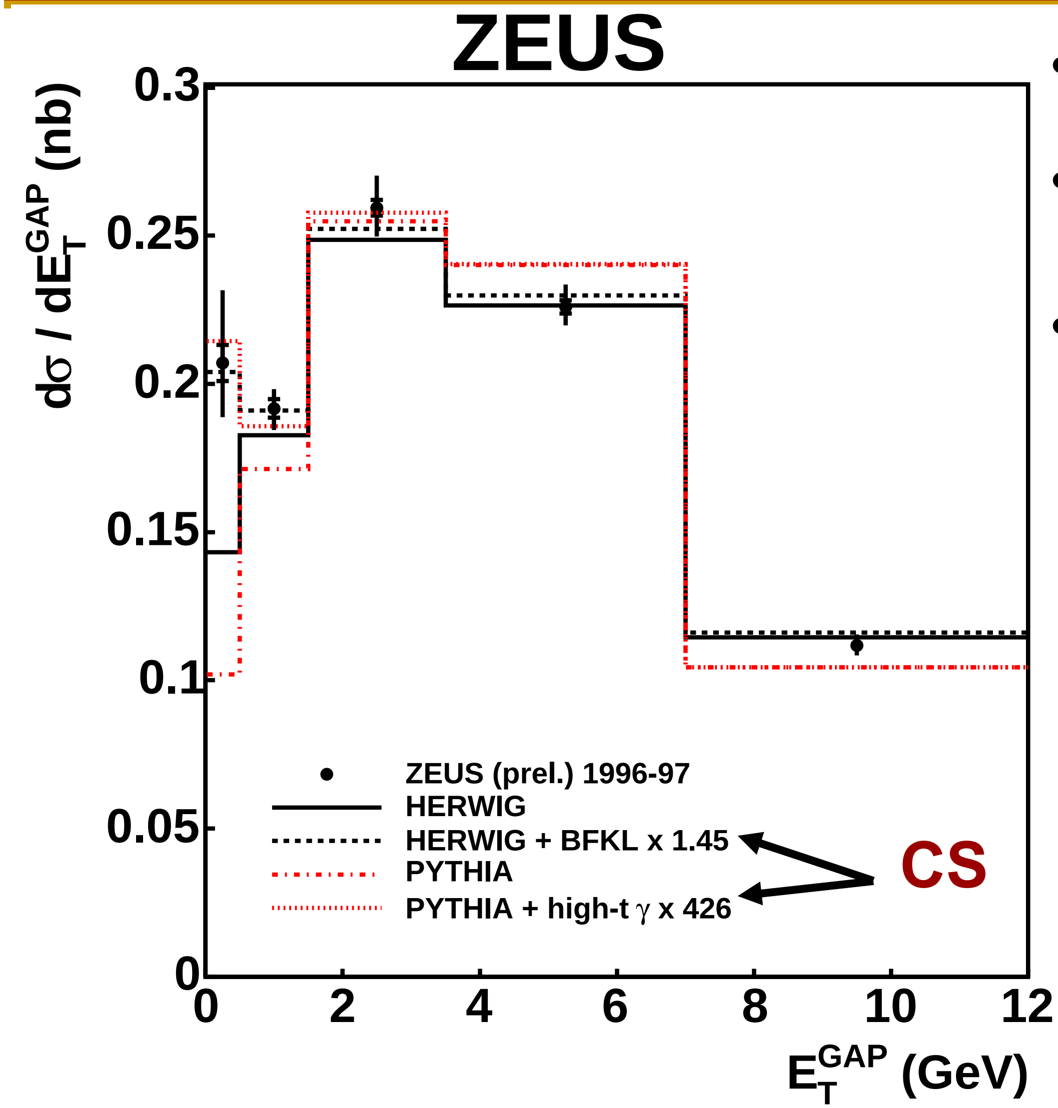
Data Acceptance Corrections

- **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$^{1/2}$	
$\vert z_{vtx}\vert < 40$ cm	$0.2 < y_{JB} < 0.85$
Dijets with Large Rapidity Separation:	
$E_T^{1,2} > 6.0, 5.0$ GeV	
$\vert\eta^{1,2}\vert < 2.4$	$\frac{1}{2}\vert\eta^1 + \eta^2\vert < 0.75$
$2.5 < \vert\eta^1 - \eta^2\vert < 4.0$ (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	

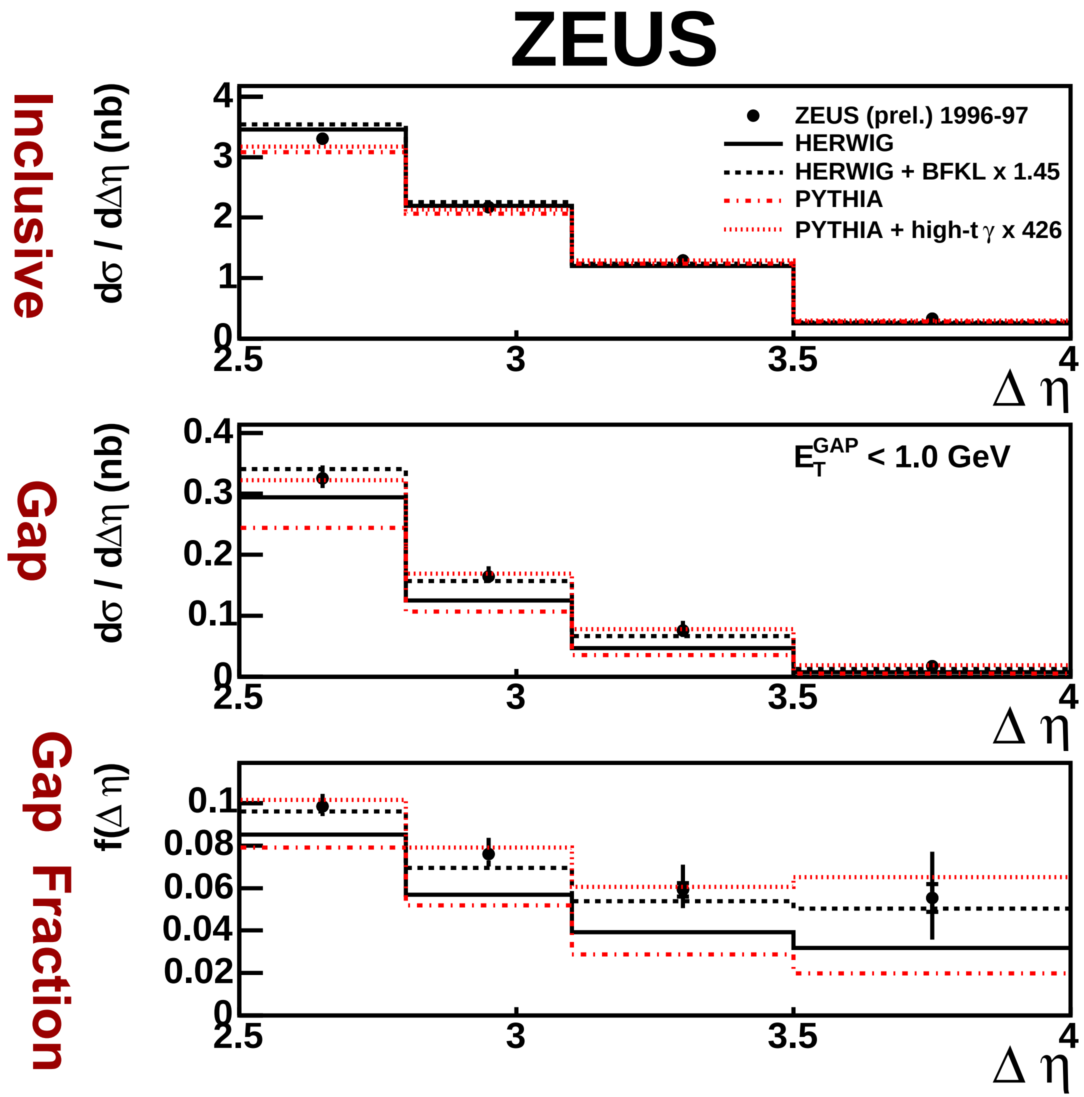
Acceptance Corrected Data vs MC
E_T^{Gap} Cross Section



- **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

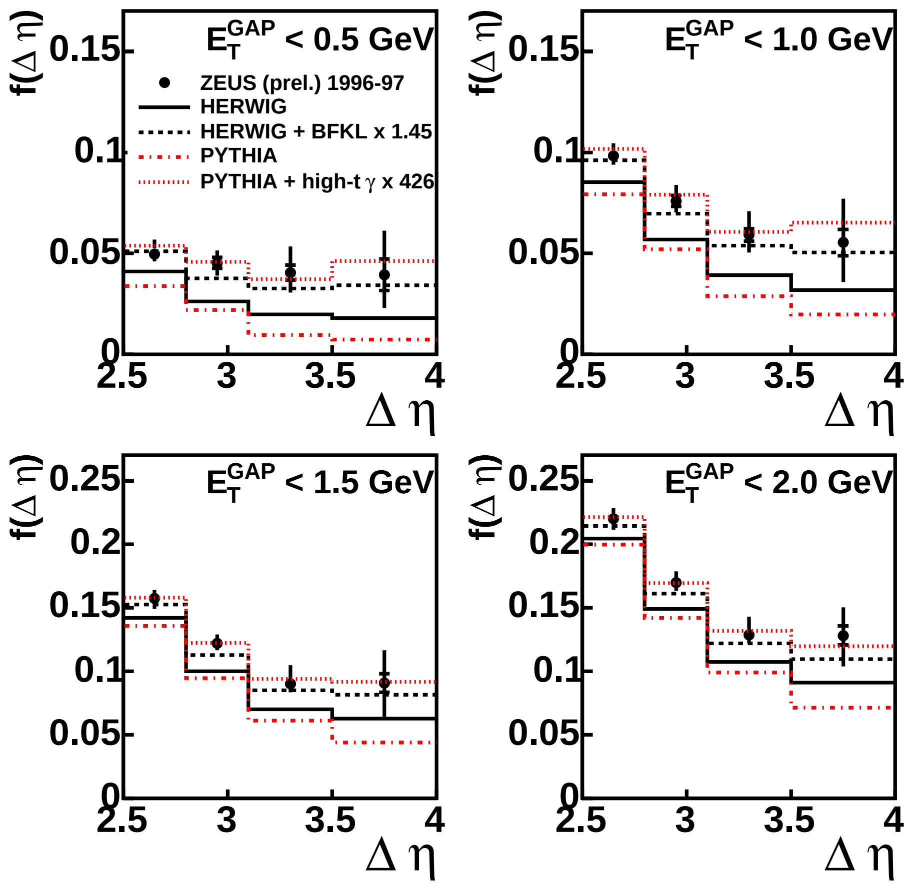
Acceptance Corrected Data vs MC $\Delta\eta$ Cross Sections



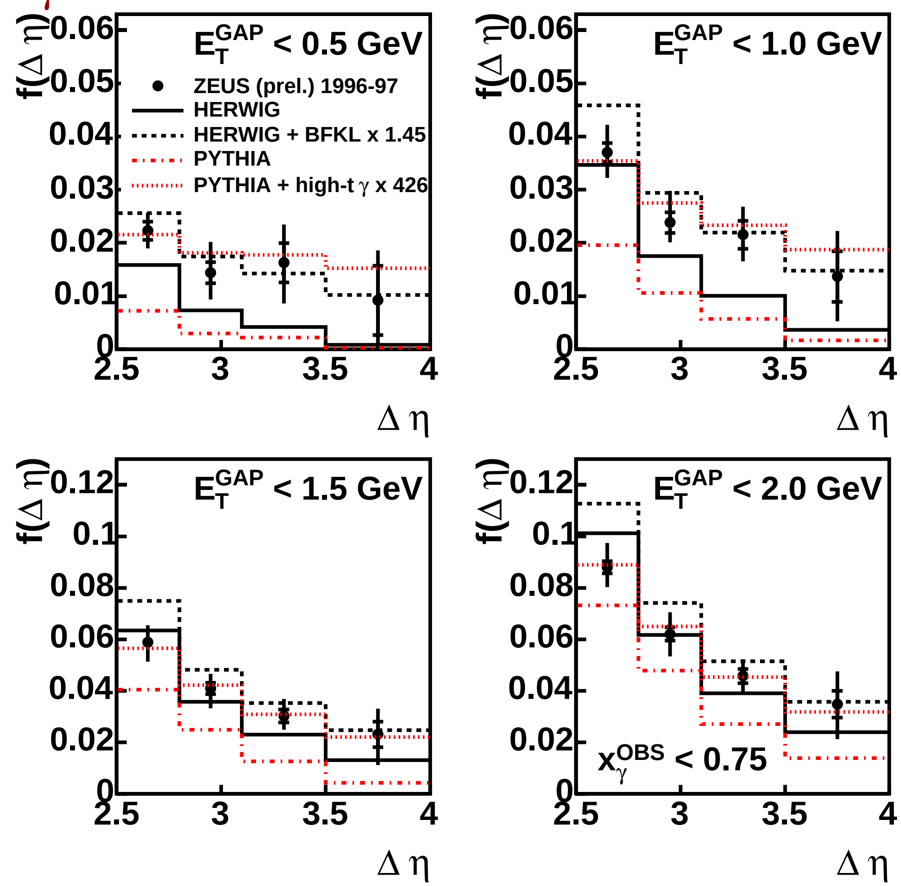
- **MC with CS added describes data**

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

All x_γ^{OBS} ZEUS



x_γ^{OBS} < 0.75 ZEUS Resolved

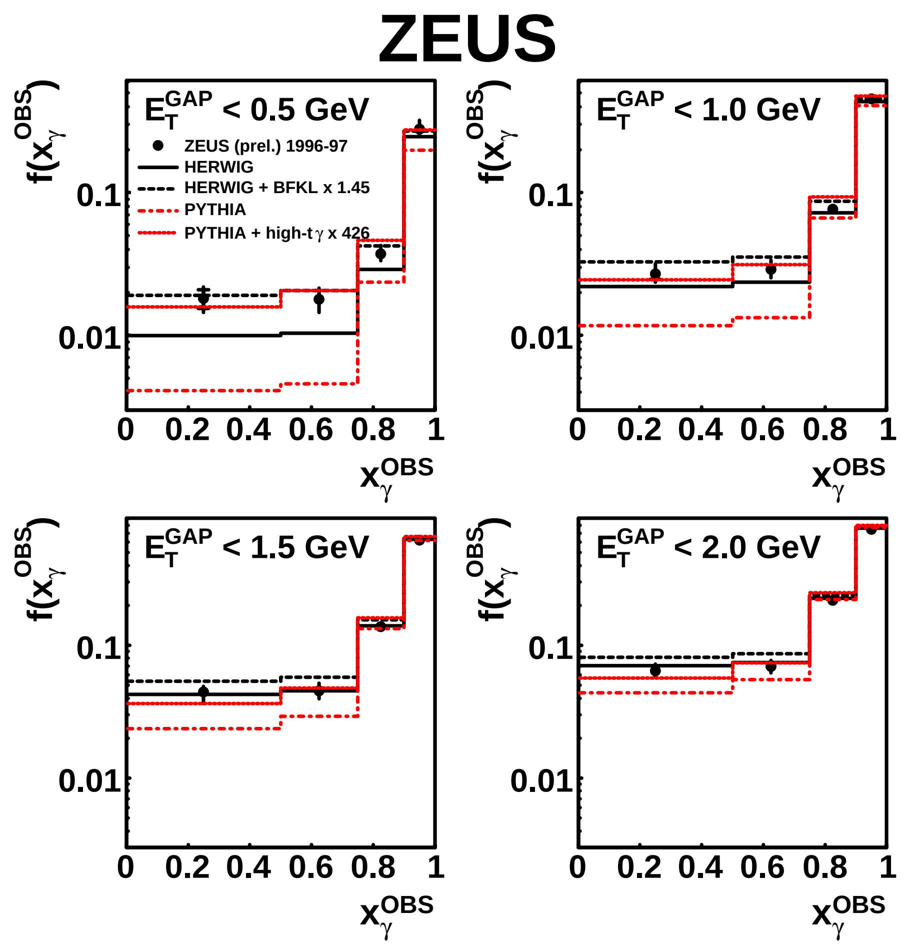


- **MC with CS describes data for entire x_γ^{OBS} region**
- **CS contribution in resolved region is 1-2%**

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

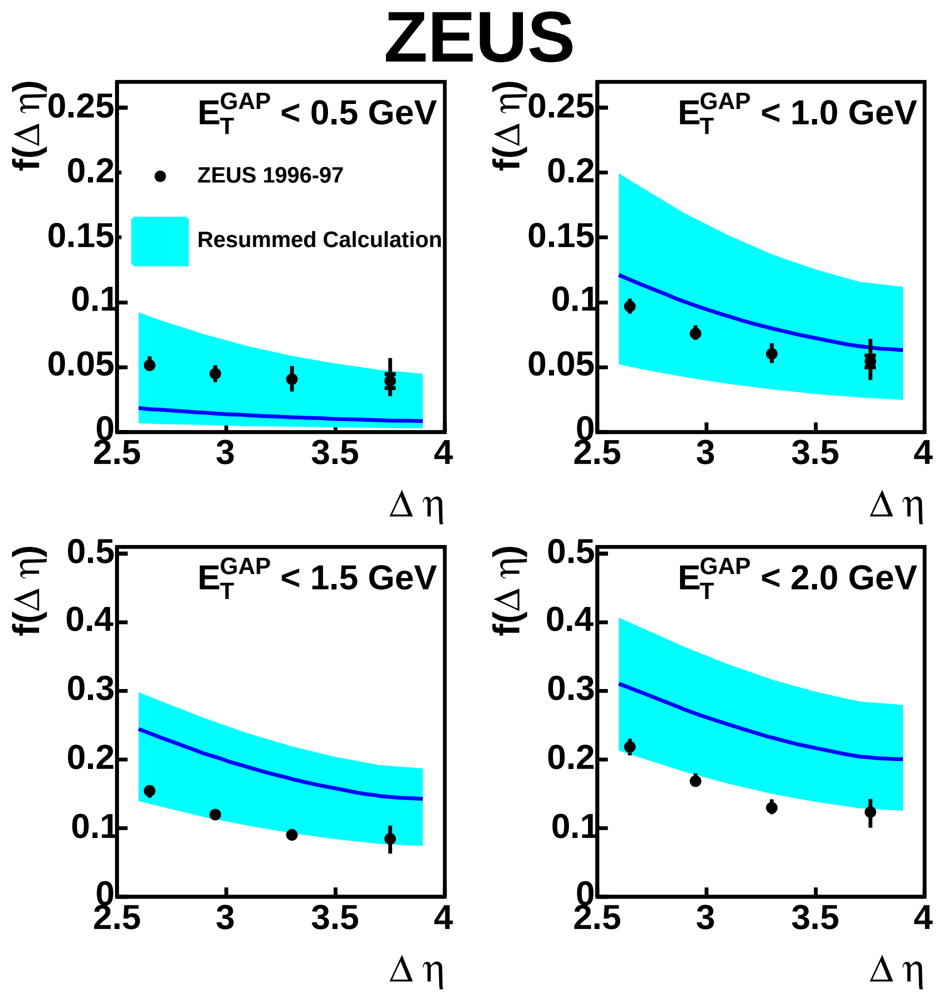
$$x_\gamma^{OBS} = \frac{\sum_{jets} E_T e^{-\eta}}{2yE_e}$$

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 $\Delta\eta$**

- **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**