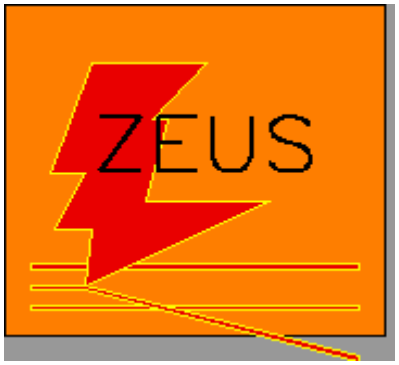
Jets Photoproduction from ZEUS

Alexander A. Savin



Workshop on
PHP at collider energies: from RHIC and HERA to LHC,
15-19 January 2007, Trento, Italy

Recent Results Interesting for LHC

- Multijet (three and four jets) photoproduction - Multi-Parton Interactions (MPI) – is almost being published ;
- Hard dijet production via color-singlet exchange – events with rapidity gap between jets (DESY-06-215)

Kinematics and Jets Reconstruction

- Kinematic variables and jets are reconstructed using Energy Flow Objects – combination of tracking and calorimeter information ;
- Jets are reconstructed using k_T algorithm in the longitudinally invariant inclusive mode.

$$Q^2<1\ \mathrm{GeV}^2,\ 0.2<y<0.85(0.75)$$

$$E_T^{jet1}>7(6)\ \mathrm{GeV},\ E_T^{jet2}>7(5)\ \mathrm{GeV},\ E_T^{jet3,4}>5\ \mathrm{GeV}$$

+ some specific cuts for each analysis

Monte Carlo Parameters and Tuning I

HERWIG + JIMMY for MPI

- Proton PDF: CTEQ 5L (CTEQ 5L)
- Photon PDF: GRV-G (SaS-G 2D)
- Square factor to reduce proton radius: 3.0 (default 1.0)
- Probability of Soft Underlying Event: 0.03 (default 1.0)
- Photon to resolve - 1/150 (default 1/300)
- Multijets: $p_T^{Min\ 1}$= 2.0 $p_T^{Min\ 2}$= 1.8 (new HERWIG)
- Jets with RG: P_T^{MIN1} = 2.7 GeV (default 1.8 GeV)

Monte Carlo Parameters and Tuning II

PYTHIA + “simple model” for MPI

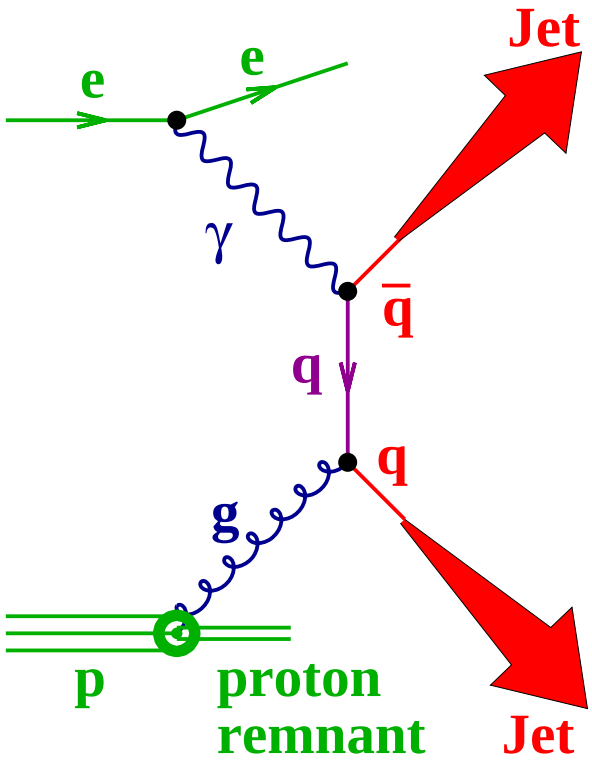
- Proton PDF: CTEQ 5L (CTEQ 5L)
- Photon PDF: GRV-G (SaS-G 2D)
- $p_T^{\text{Min } 1} = 2.0$ $p_T^{\text{Min } 2} = 1.5$ (1.9 GeV, 1.7 GeV)

For the multijets publication default values

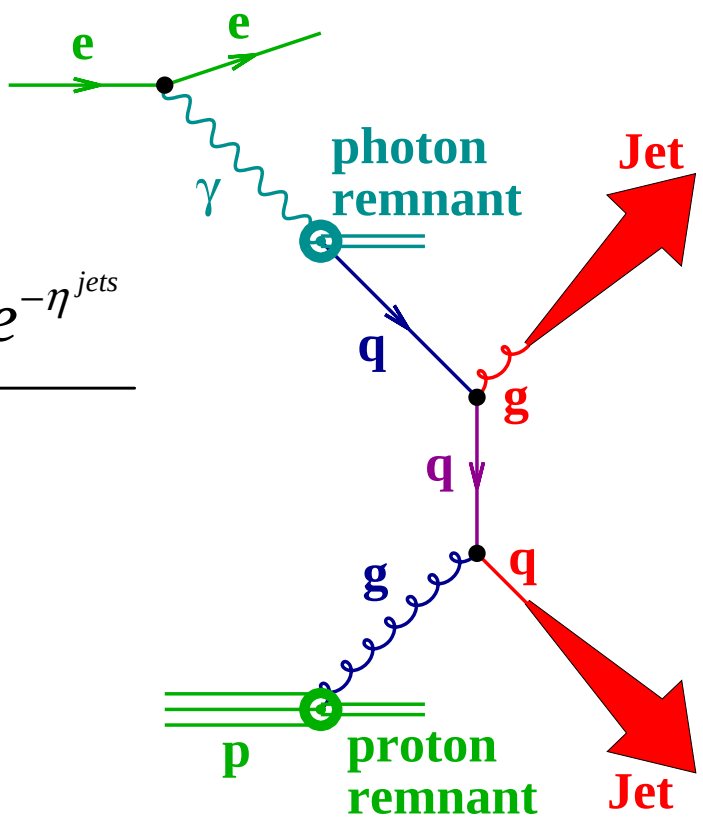
$p_T^{\text{Min } 1} = 2.5$ $p_T^{\text{Min } 2} = 1.9$ are used

- Cross sections have to be scaled to describe the data normalization

Direct and Resolved PHP



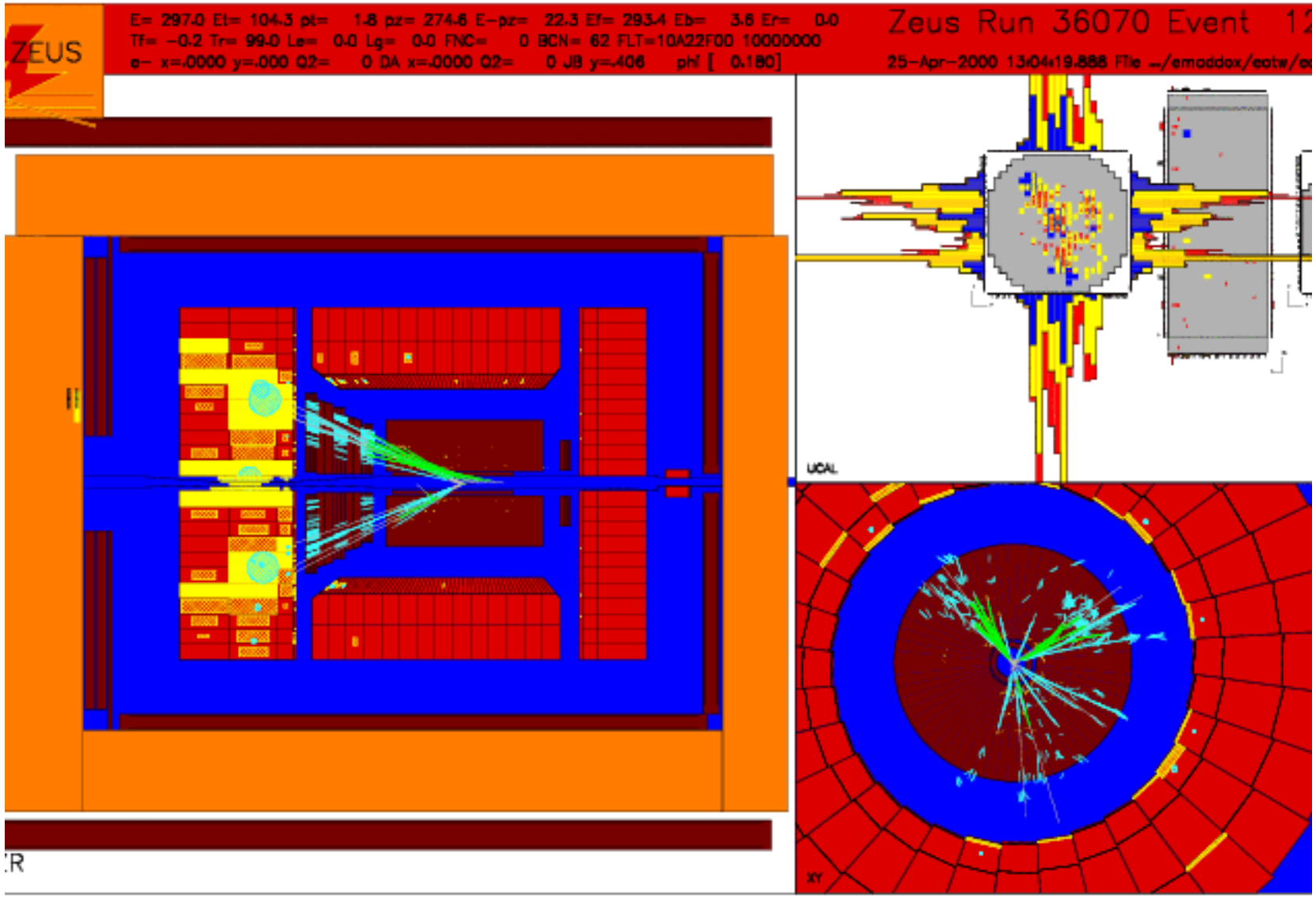
$$x_\gamma^{obs} = \frac{\sum_{jets} E_T^{jet} e^{-\eta^{jets}}}{2E_\gamma}$$



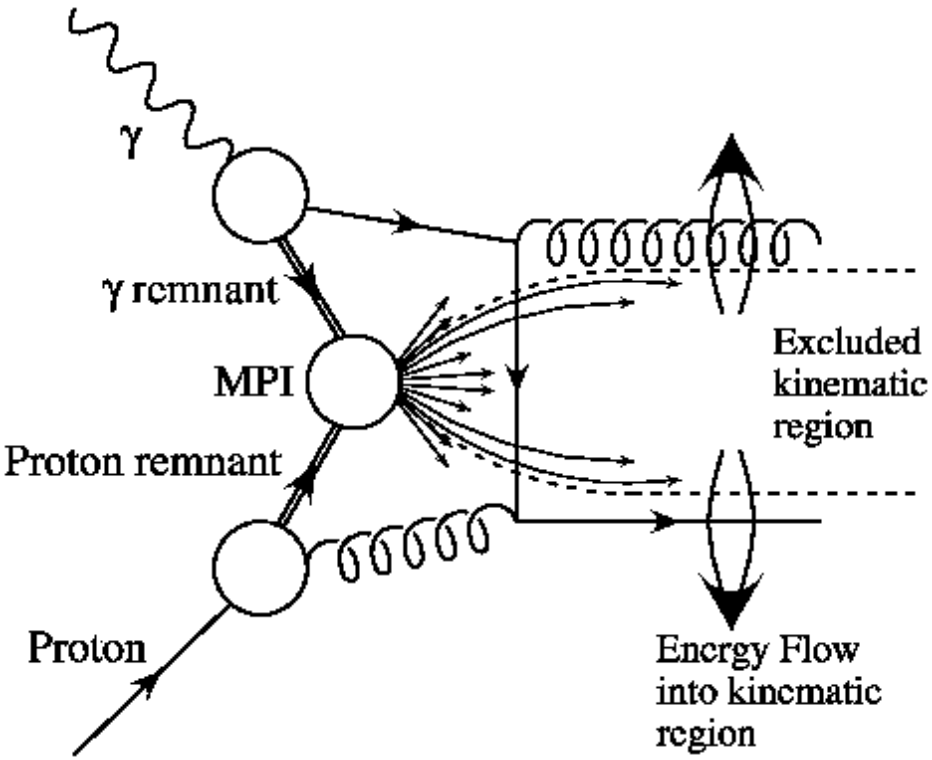
$x_\gamma^{obs} > 0.75$

$x_\gamma^{obs} < 0.75$

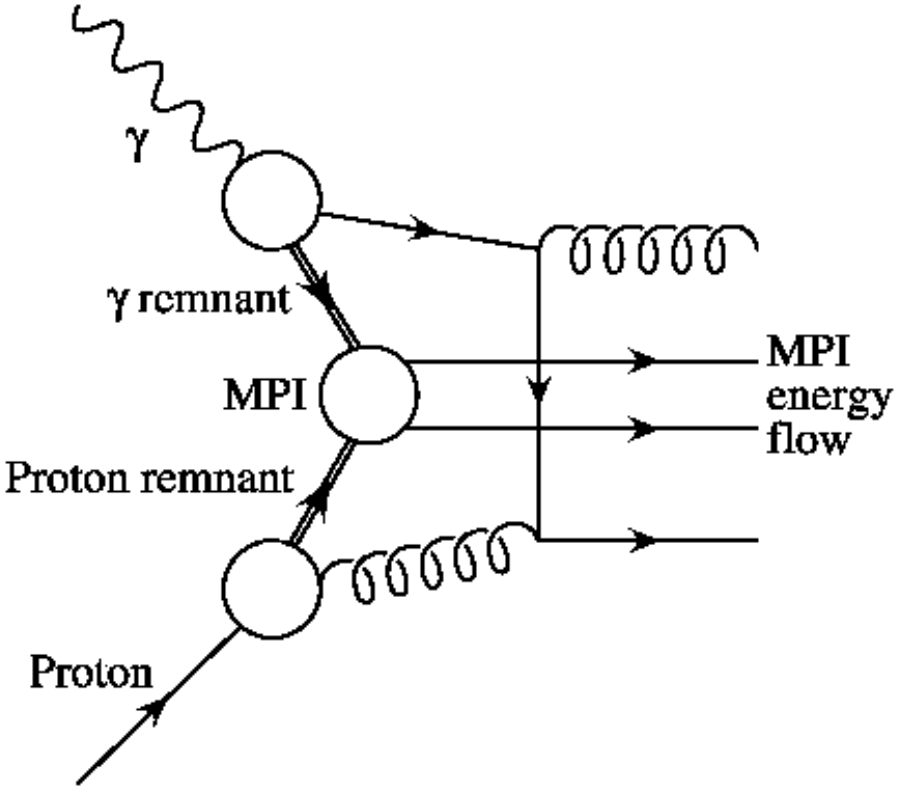
Three Jets at ZEUS



Multijets: Soft and Hard MPI

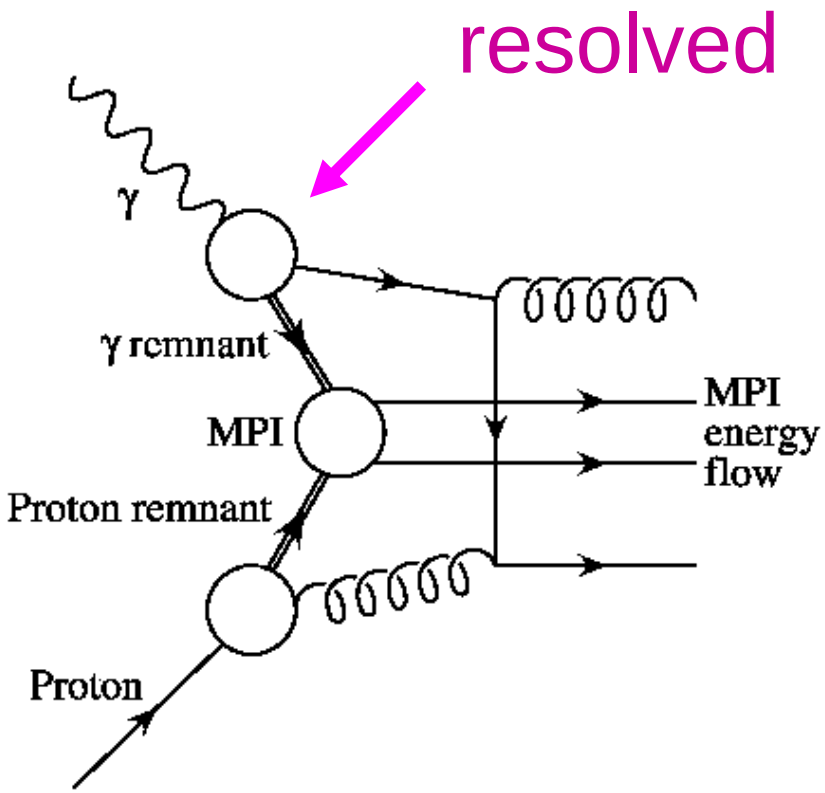


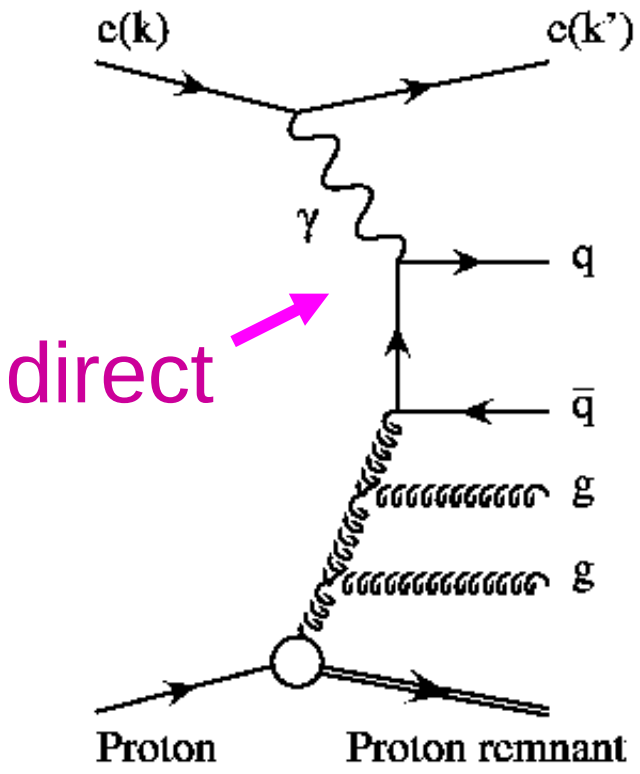
Moving jets into the kinematic region



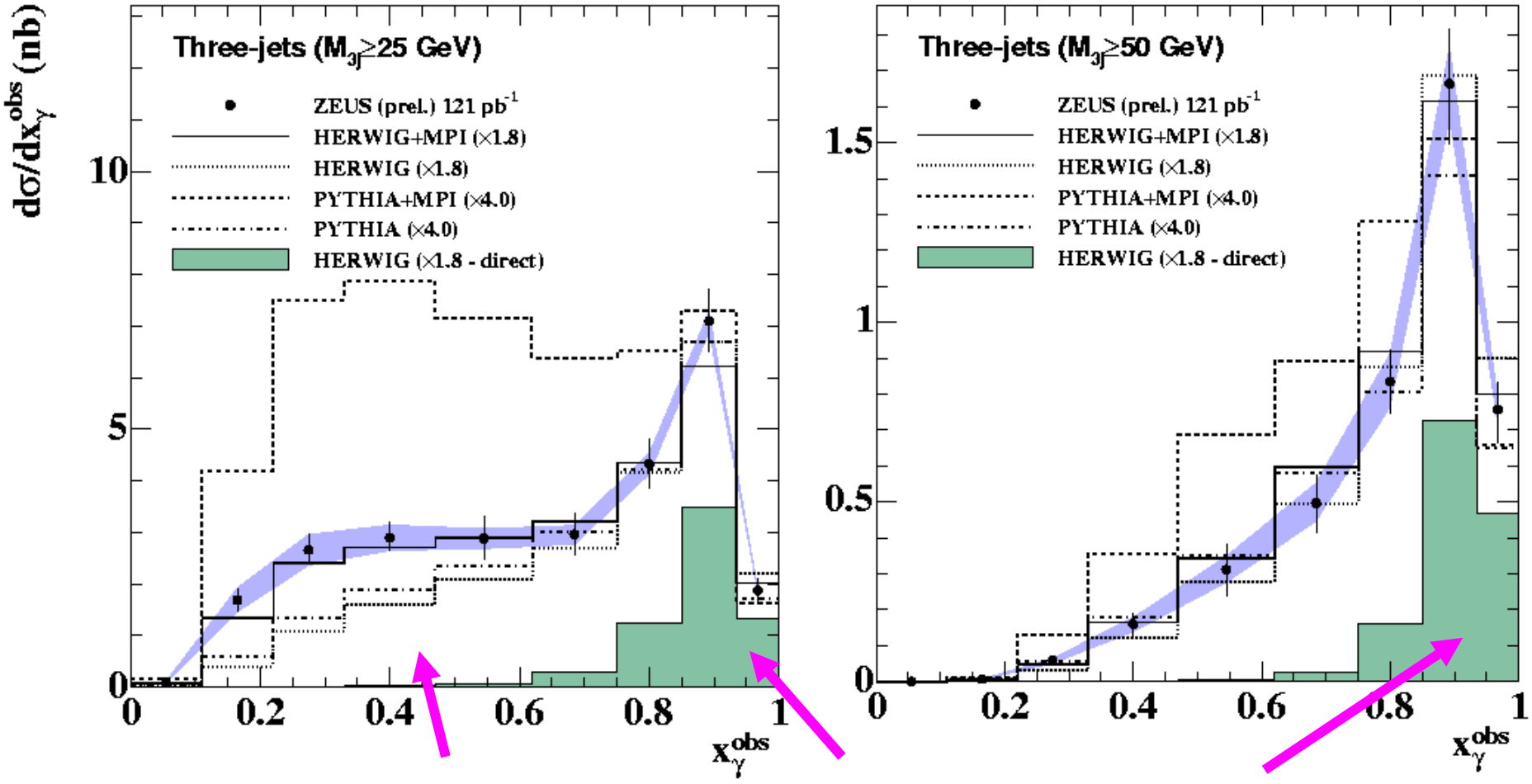
Adding jets

Hard MPI and LO Four Jets





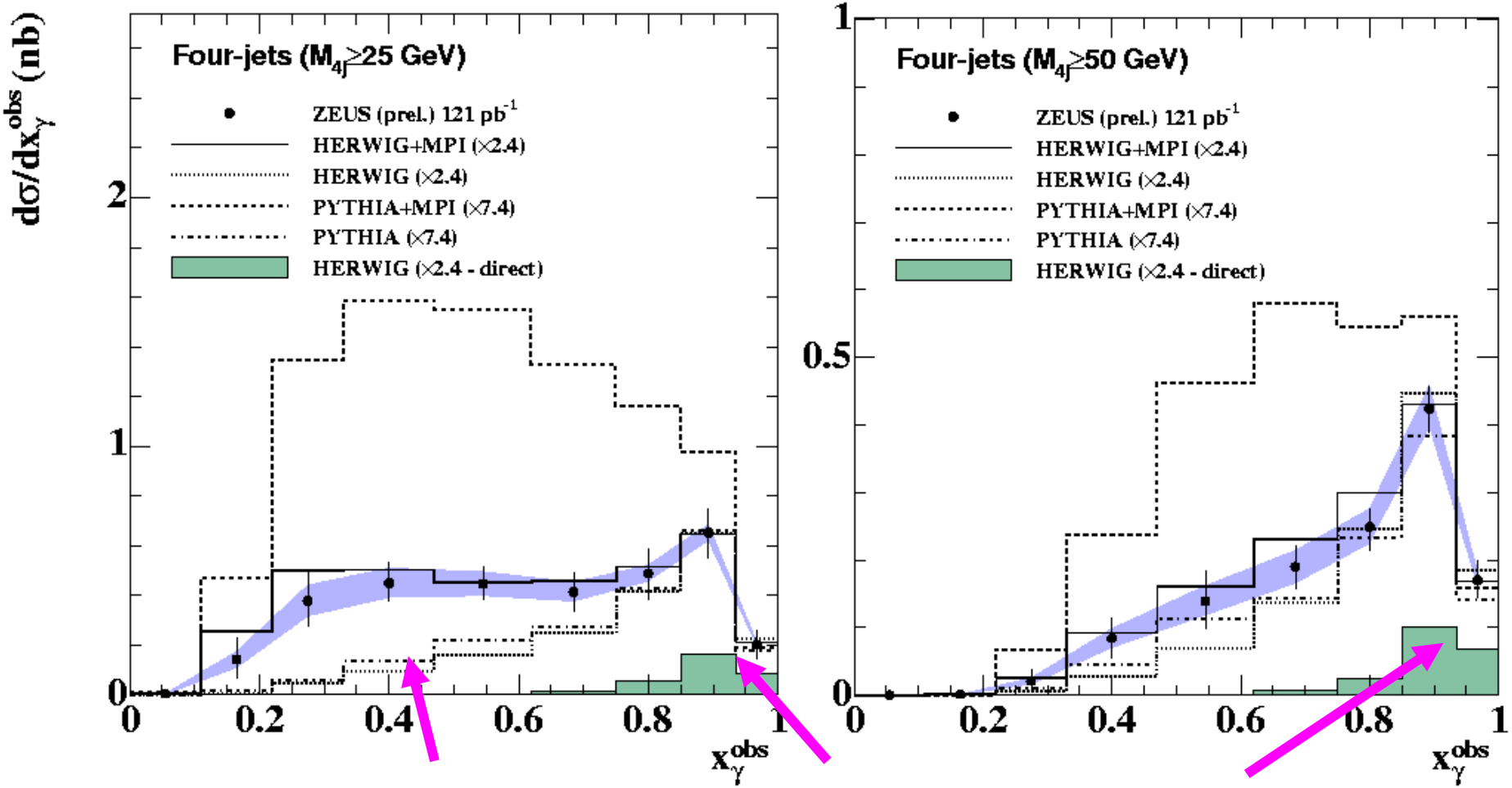
x_γ^{obs} -distributions



Low x-region

Direct contribution

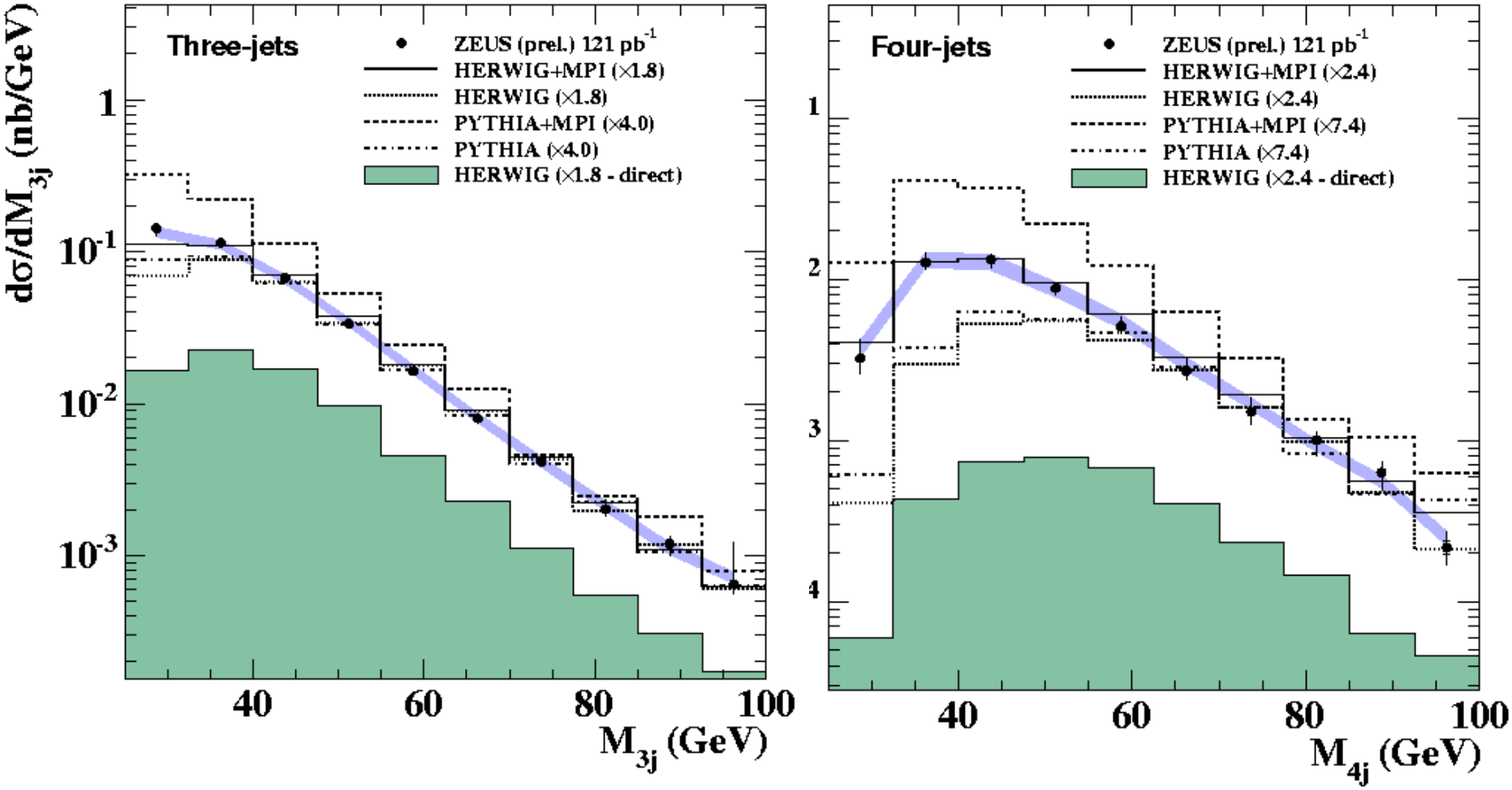
x_γ^{obs} -distributions



Low x-region

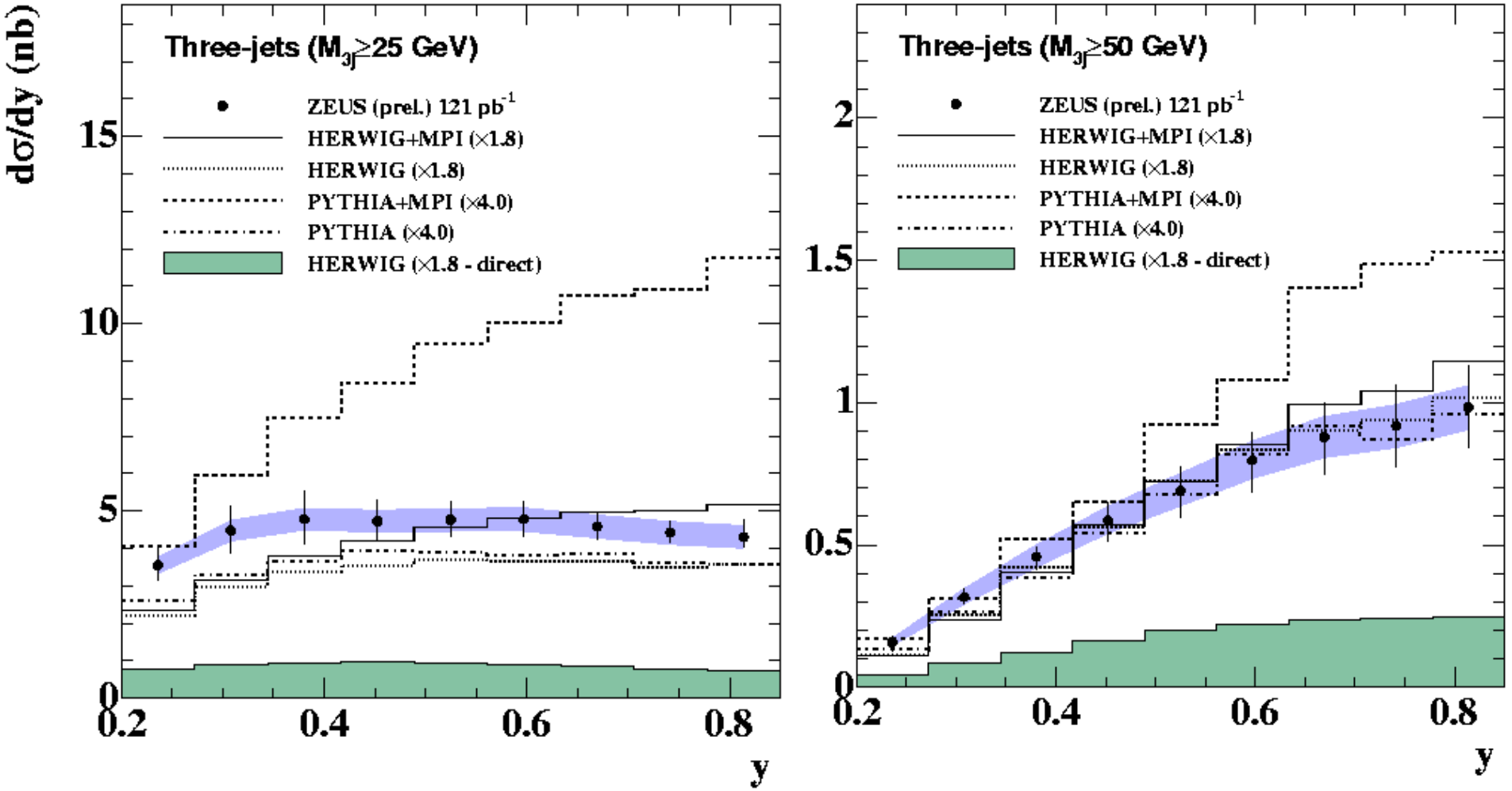
Direct contribution

Jet Mass Distributions



High mass tail is described even without MPI

y-distribution

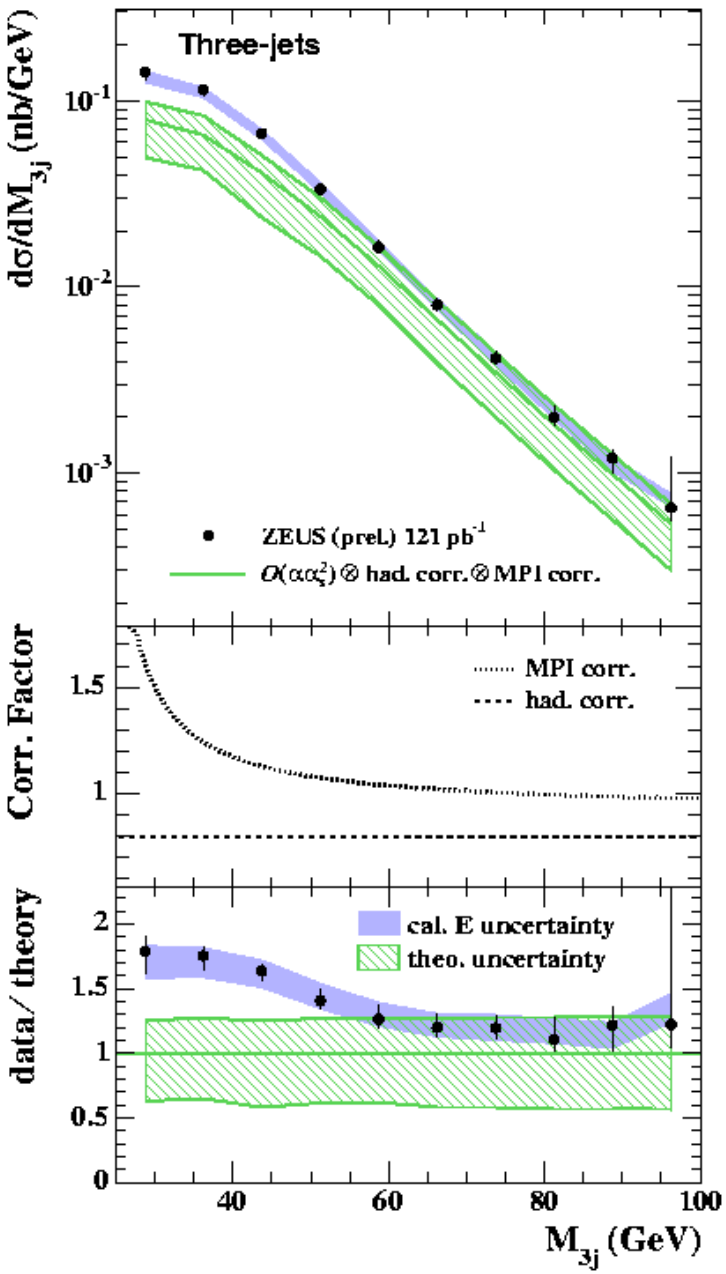


The pQCD Calculation

$O(\alpha\alpha_s^2)$

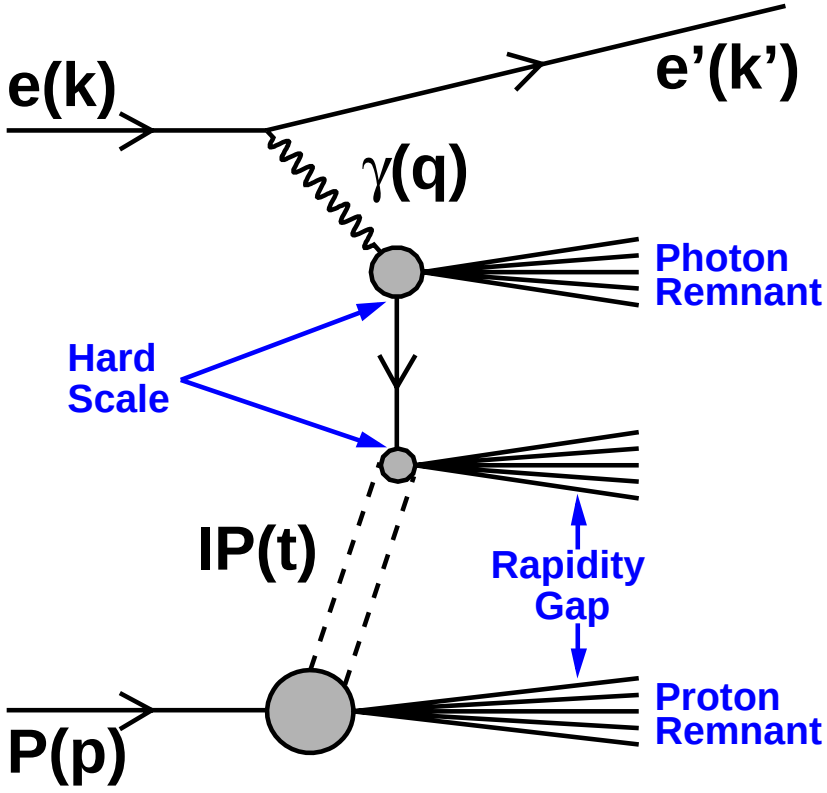
by Klasen,Kleinwort,Kramer

Average hadronization and MPI corrections from HERWIG and Pythia. E_T^{jet1} as renormalization and factorization scales

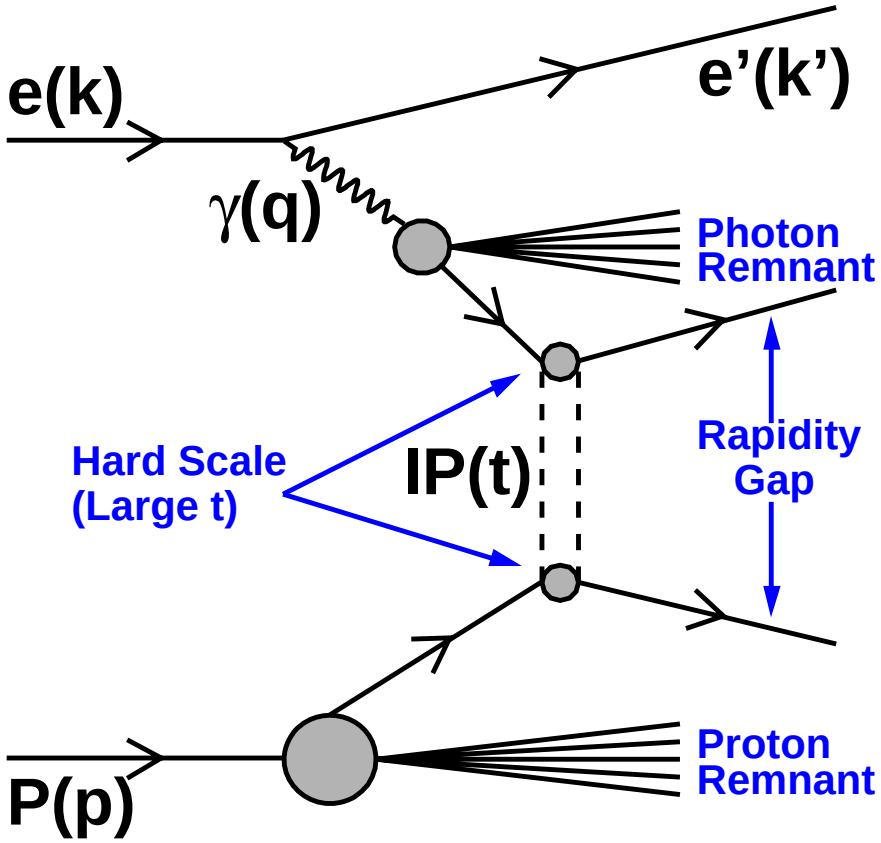


Hard Diffractive Dijet Photoproduction

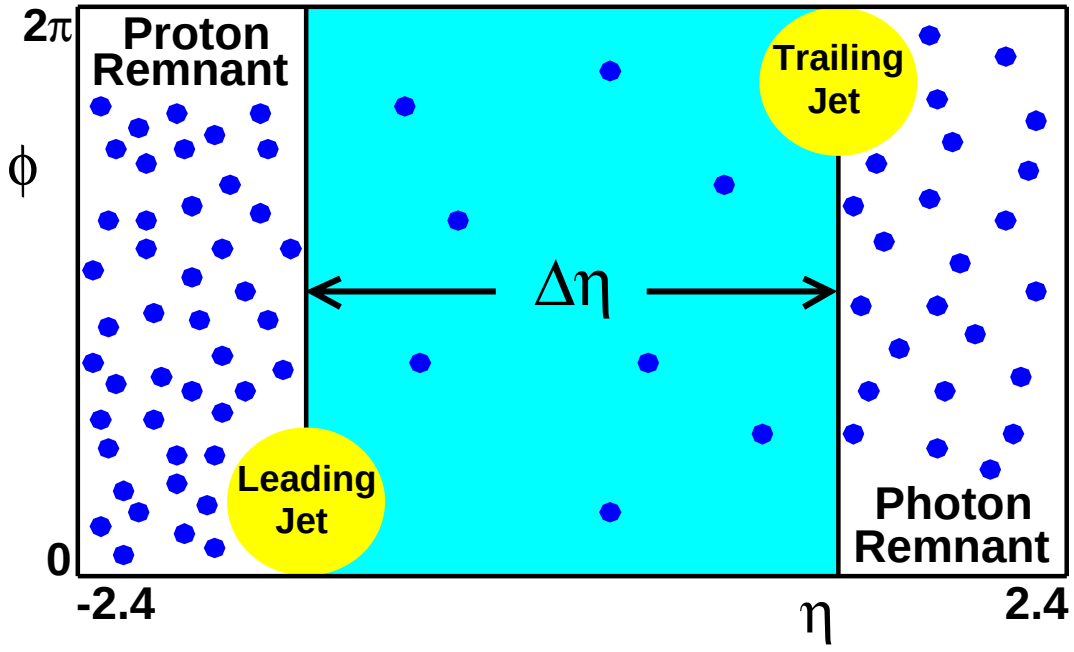
Rapidity Gap Between Jets and Proton Remnant



Rapidity Gap Between Jets



Rapidity Gap Topology



- Distance between leading and trailing jet centers: $\Delta\eta$
- Gap definition based on E_T : E_T^{Gap} - total E_T between leading and trailing jet centers

The Gap Fraction f(Δη)

Dijet Events with large Rapidity separation between jets

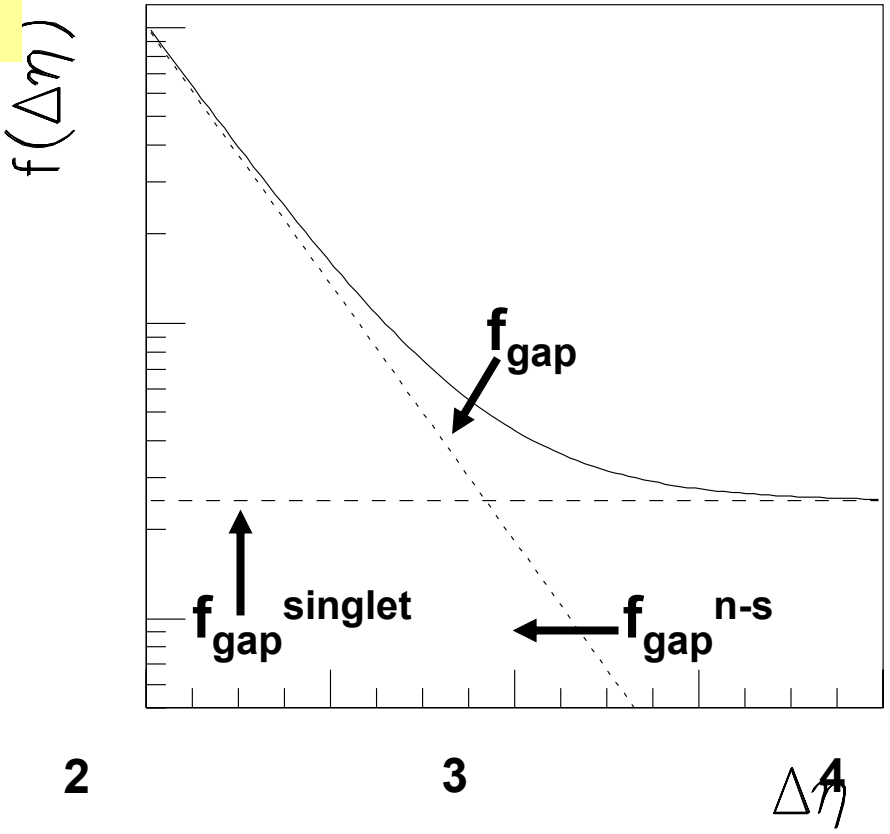
& $E_T^{Gap} < E_T^{Cut}$

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

All Dijet Events with large Rapidity separation between jets

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

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



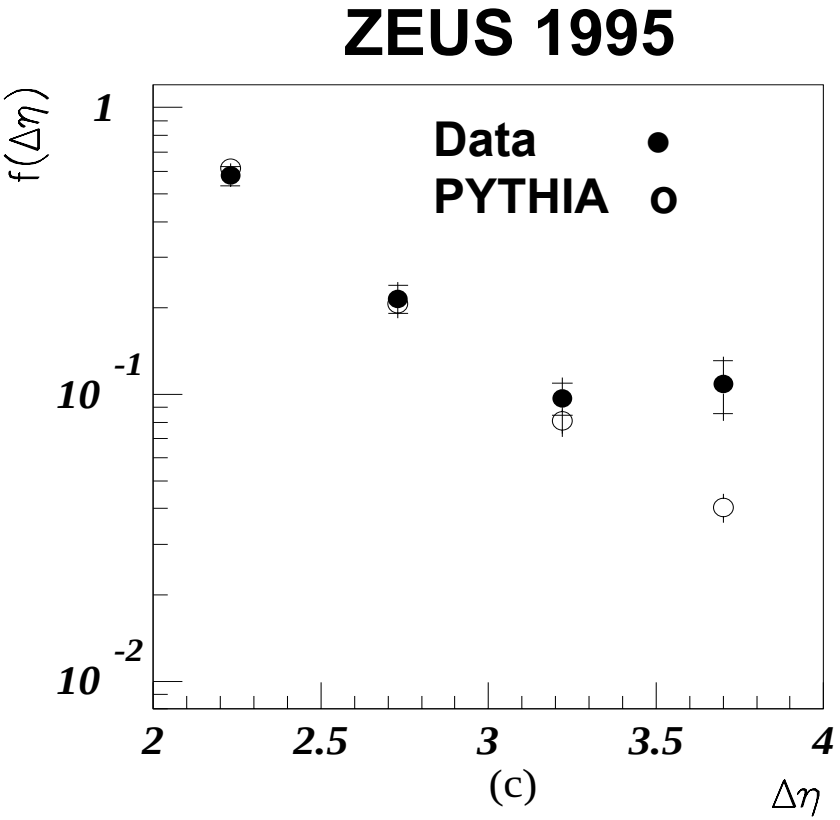
Color-Singlet Exchange in the MC

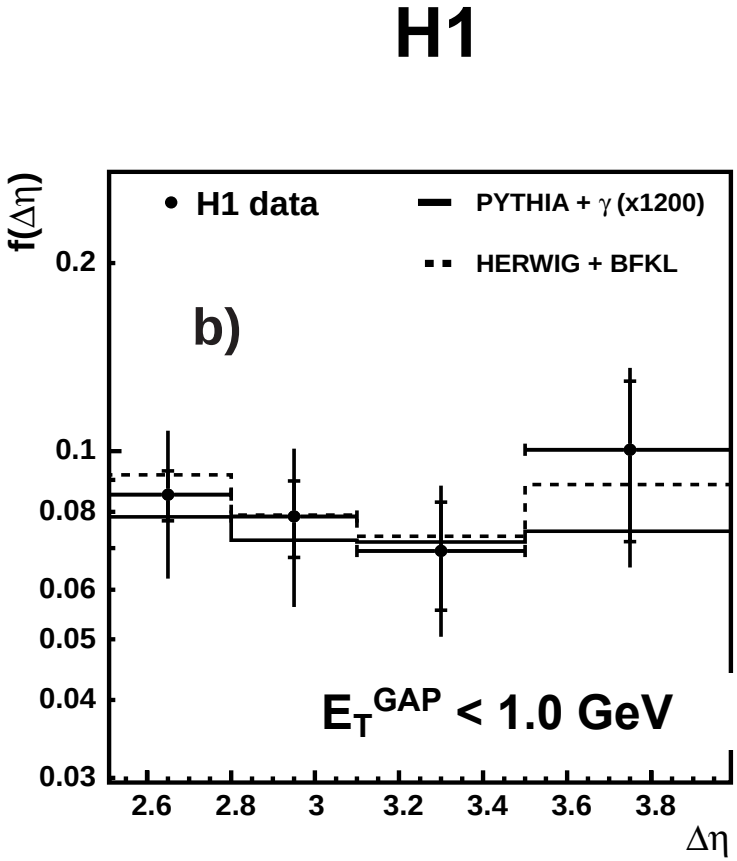
HERWIG: BFKL Pomeron as exchange object

PYTHIA: High-t γ exchange

- Used to match data only – Rapidity Gap not due to photon exchange

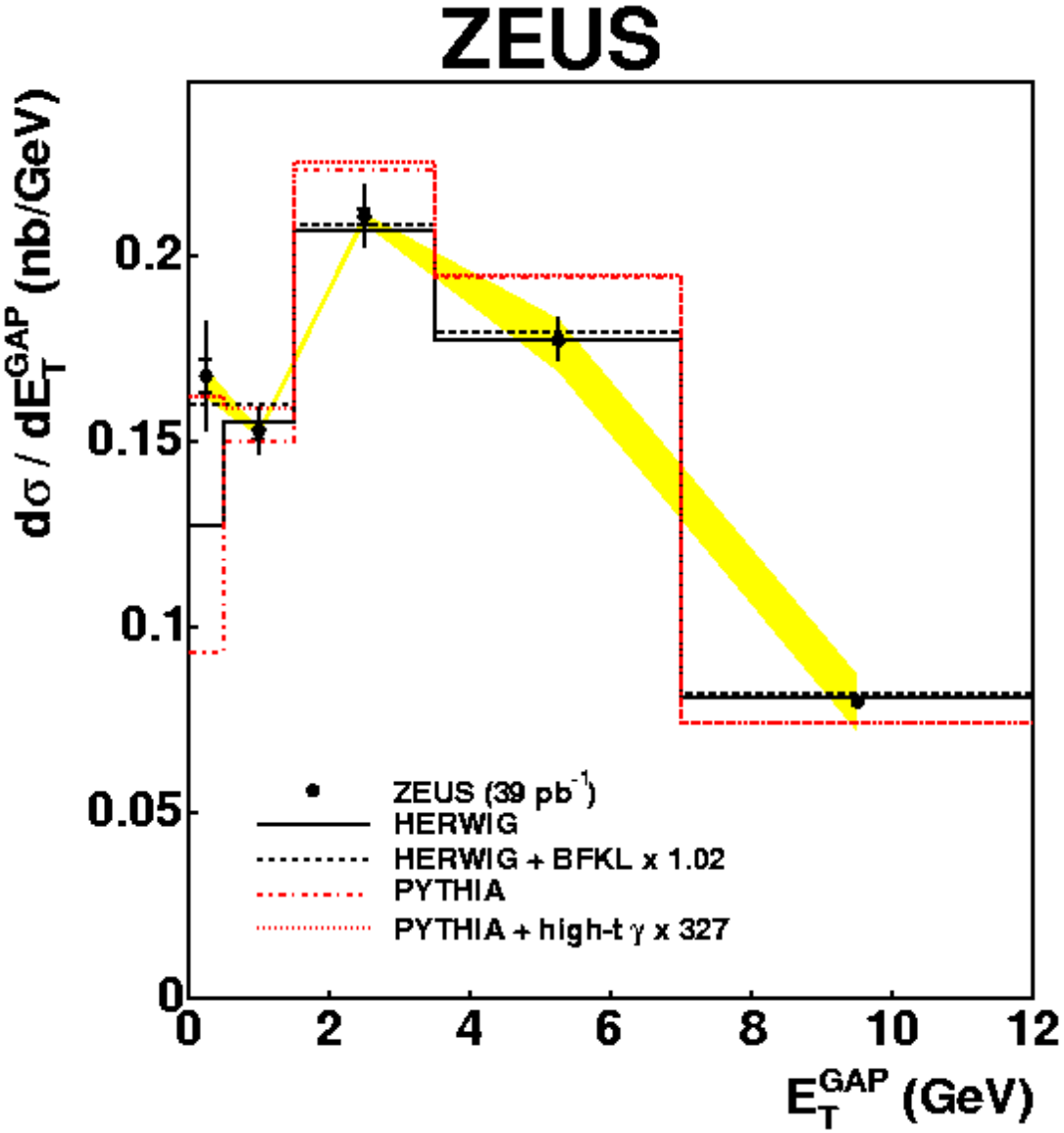
Previous HERA Measurements





- ZEUS 1995: Gap Fraction defined by multiplicity
- H1 2002: Gap Fraction defined by E_T^{Gap}

Cross Section Estimate of the CS



$$2.5 < \Delta\eta < 4$$

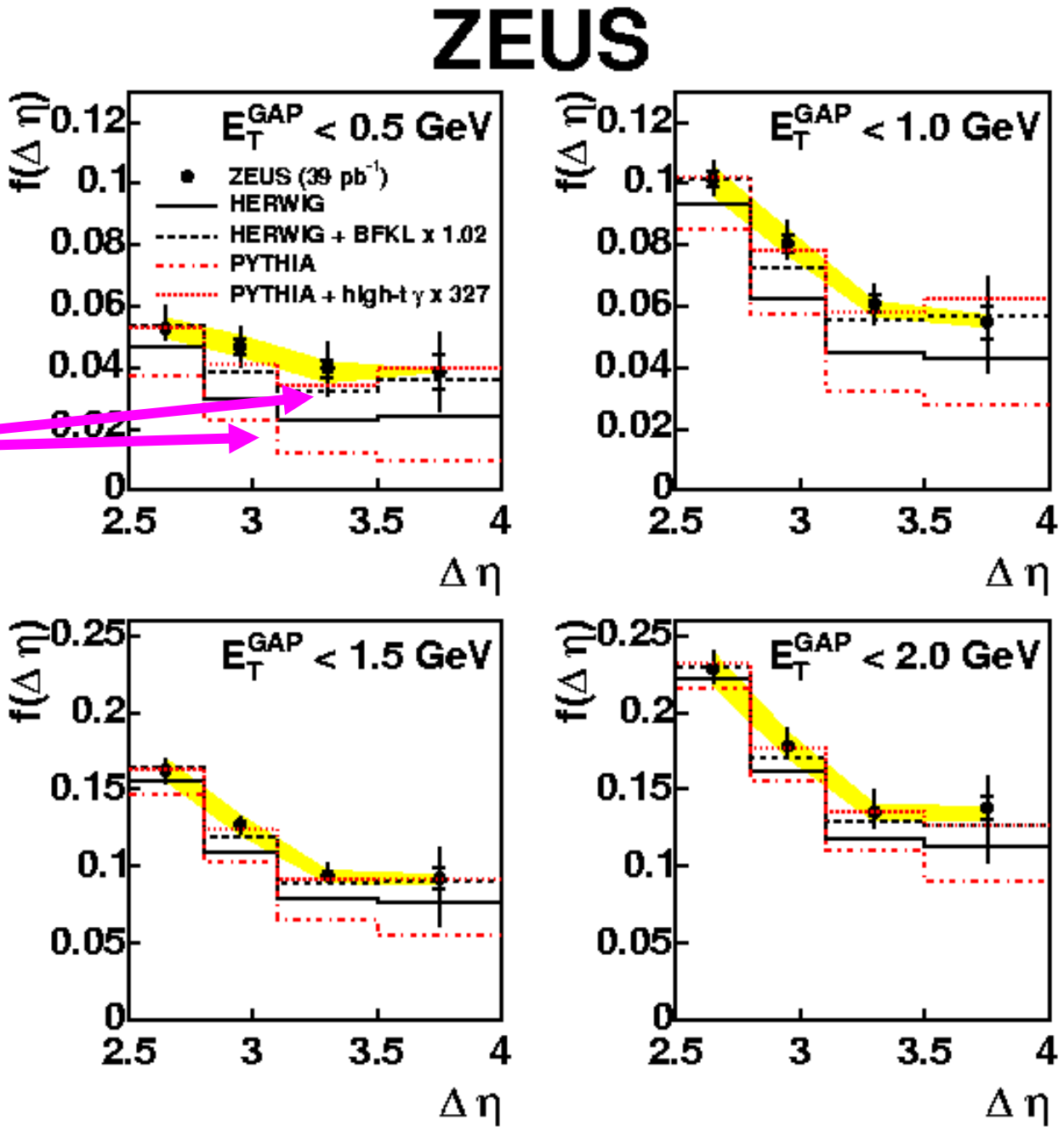
HERWIG

$$(2.04 \pm 0.25)\%$$

Pythia

$$(2.75 \pm 0.10)\%$$

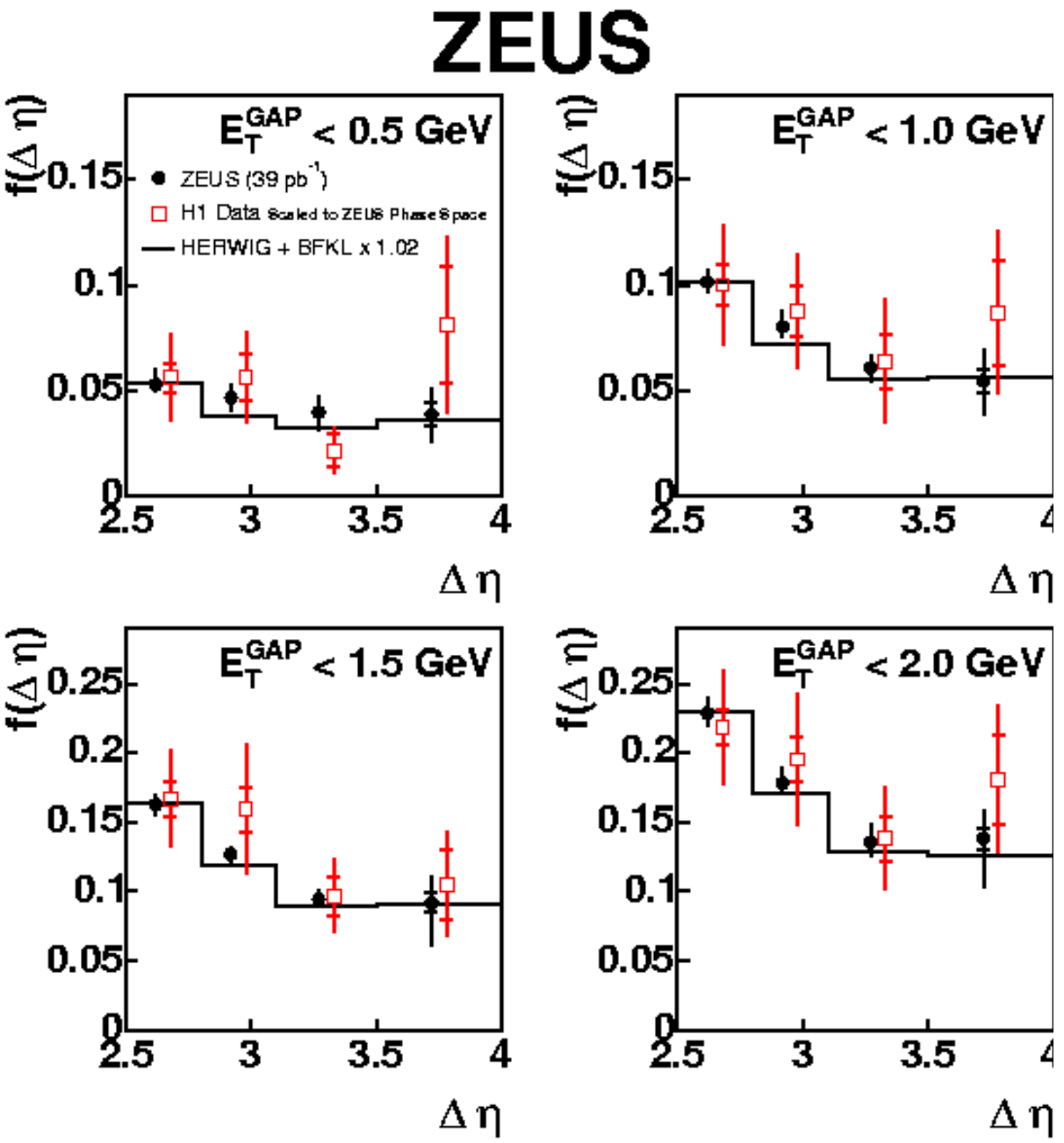
Gap Fraction



This difference
Is the CS
contribution

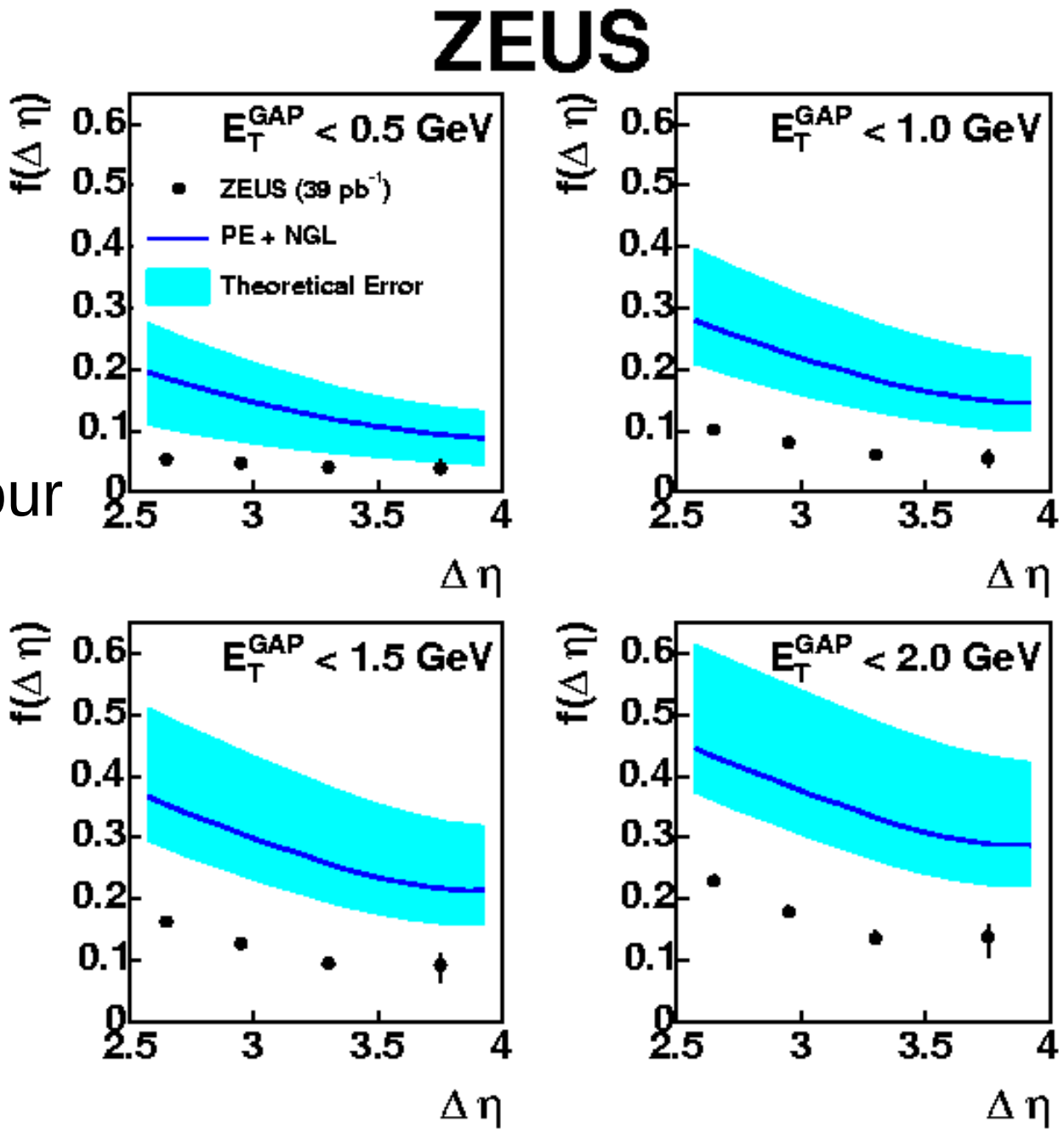
Data are well
described
by the MC

Comparison to H1



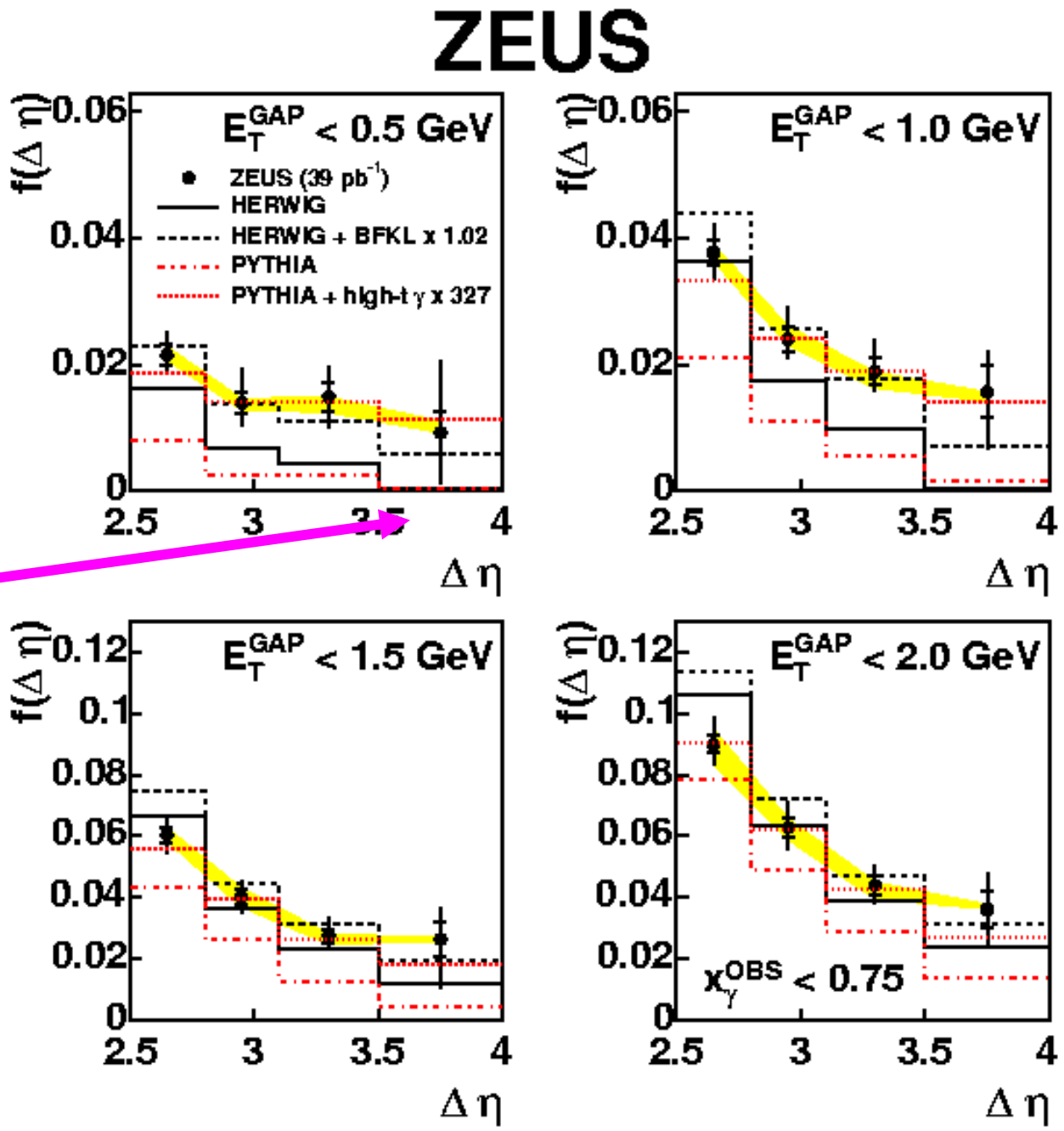
Resummed Calculation

Appleby, Banfi, Dasgupta, Seymour

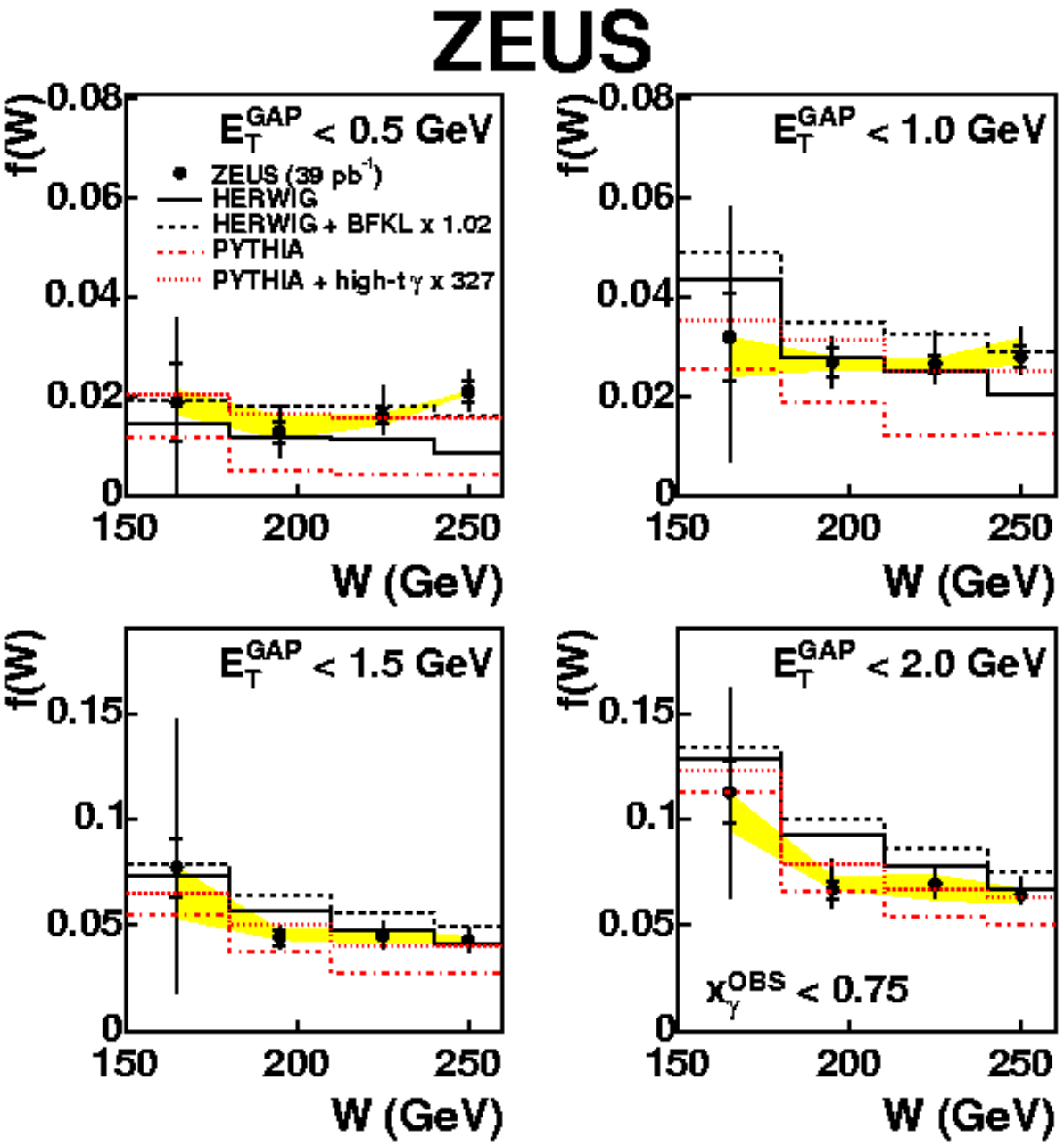


Resolved Contribution

CS only



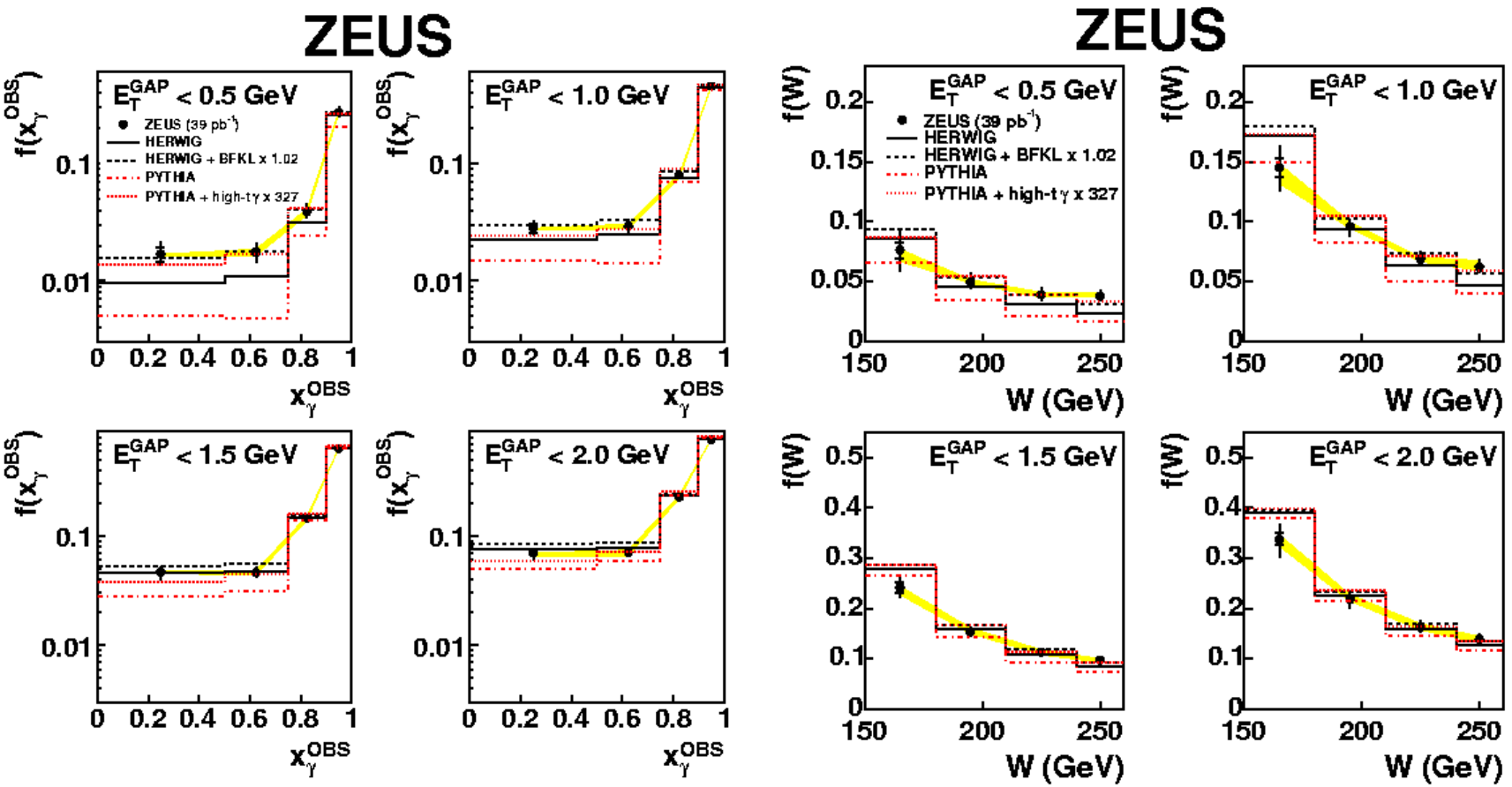
Resolved Contribution: Energy Dependence

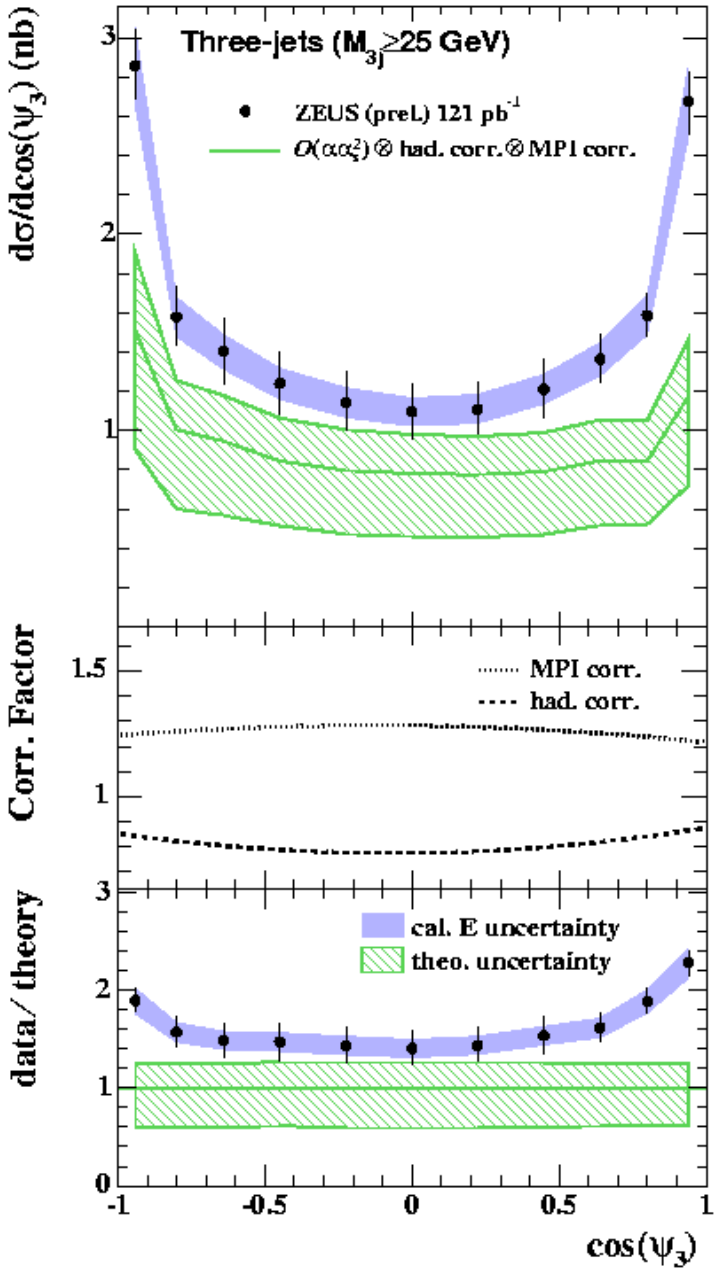


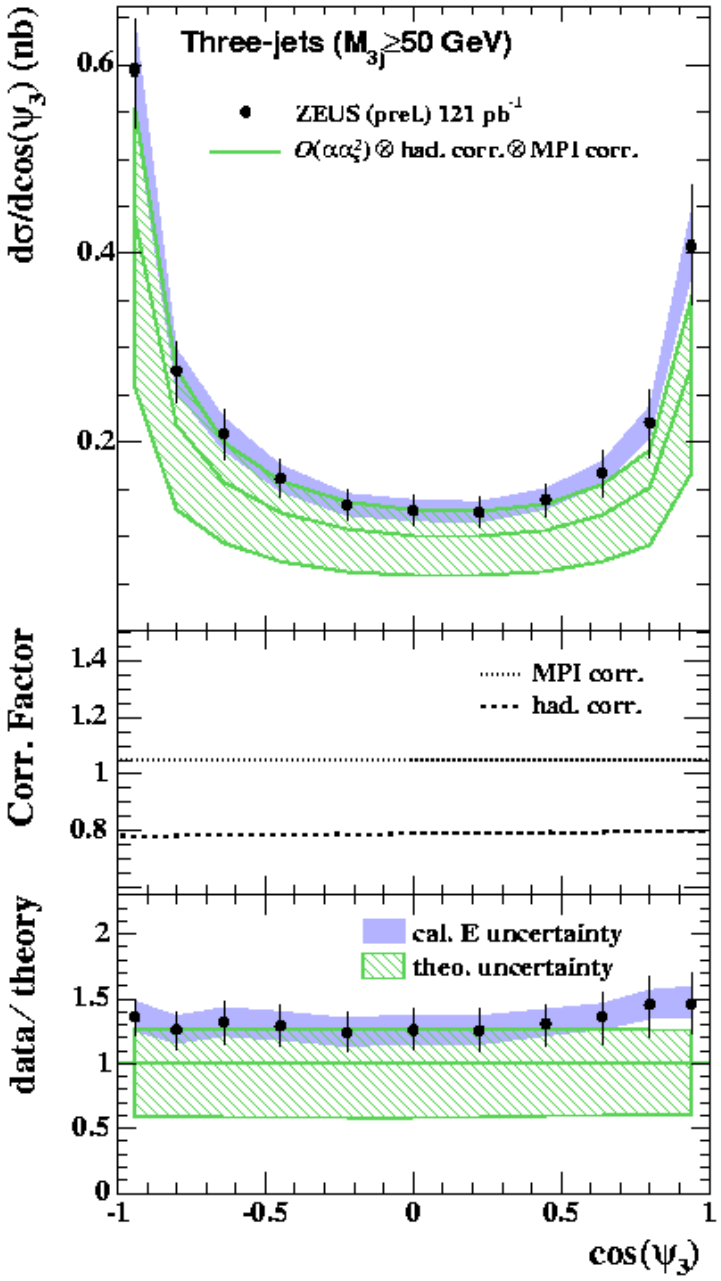
Conclusions

HERA has collected a lot of information which can be used for better understanding of physics and tuning the models also for LHC …

Will we get use of it ?


ZEUS
ZEUS
E_T^{GAP} < 0.5 GeV
E_T^{GAP} < 1.0 GeV
E_T^{GAP} < 1.5 GeV
E_T^{GAP} < 2.0 GeV
ZEUS (39 pb^{-1})
HERWIG
HERWIG + BFKL x 1.02
PYTHIA
PYTHIA + high-tγ x 327
$f(x_\gamma^{OBS})$
x_γ^{OBS}
f(W)
W (GeV)


Three-jets (M_{3j}≥25 GeV)
ZEUS (preL) 121 pb^{-1}
$O(\alpha\alpha_s^2)$ ⊗ had. corr. ⊗ MPI corr.
dσ/dcos(ψ_3) (nb)
MPI corr.
had. corr.
Corr. Factor
cal. E uncertainty
theo. uncertainty
data / theory
cos(ψ_3)


Three-jets (M_{3j}≥50 GeV)
ZEUS (preL) 121 pb^{-1}
$O(\alpha\alpha_s^2)$ ⊗ had. corr. ⊗ MPI corr.
dσ/dcos(ψ_3) (nb)
MPI corr.
had. corr.
Corr. Factor
cal. E uncertainty
theo. uncertainty
data / theory
cos(ψ_3)