Factorization Breaking in Diffractive Dijet Production

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August 28, 2008

Publications

- With Michael Klasen

- PLB 508 (2001) 259: $\gamma p \to 2$ jets+n
- EPJC 38 (2004) 39: $\gamma p \to 2$ jets+p
- PRL 93 (2004) 232002: $\gamma^* p \to 2$ jets+p
- JPG 31 (2005) 1391: New fact. scheme

  arXiv:0806.2269 Review based on H1 and ZEUS data

Motivation

Hard diffraction:

→ Does factorization hold?

Deep inelastic scattering: Yes

→ Direct photoproduction

Hadroproduction: No

→ Resolved photoproduction

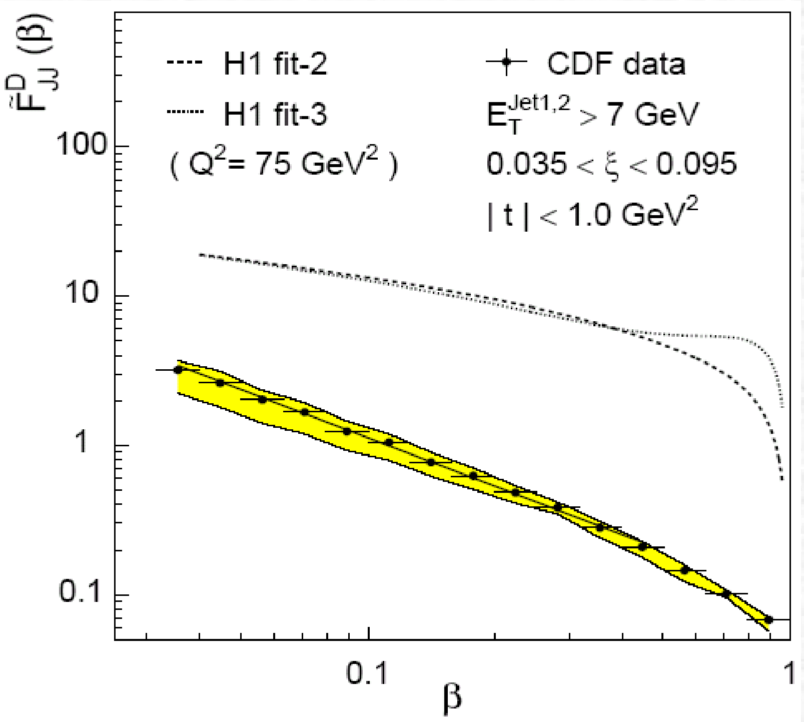
Why next-to-leading order?

→ $\sigma_{tot} = \sigma_{dir}(x_\gamma, M_\gamma) + \sigma_{res}(x_\gamma, M_\gamma)$

→ At LO $x_\gamma = 1$, but at NLO $x_\gamma \leq 1$

→ $\log(M_\gamma)$-dependence cancels

Diffr. hadroproduction of dijets:



CDF Coll., PRL 84 (2000) 5043

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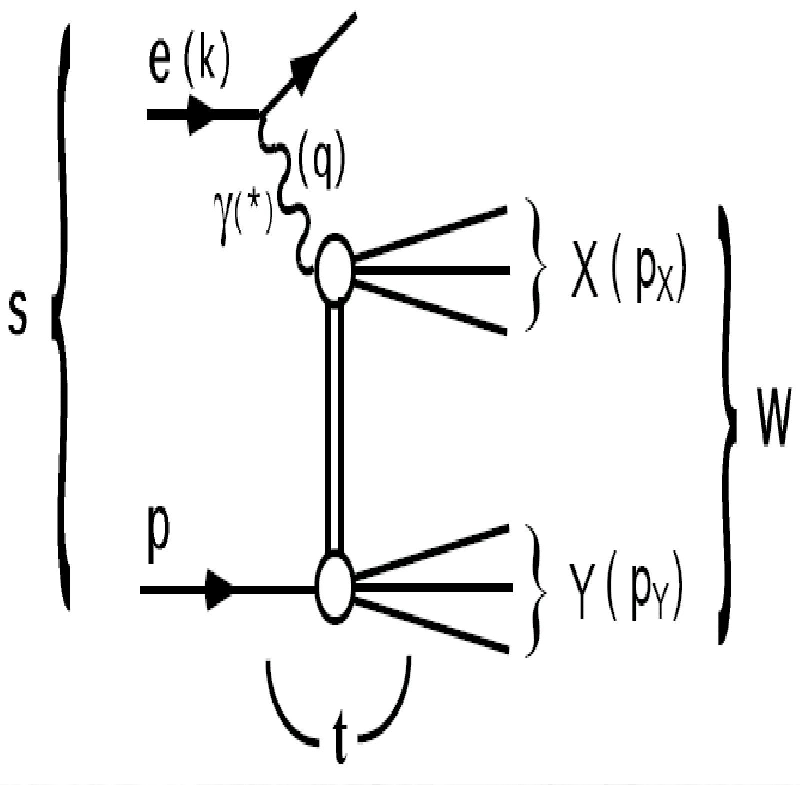
Kinematics

Diffractive processes at HERA:



H1 Coll., EPS 2003 and DIS 2004

Inclusive DIS:

$$s = (k+p)^2, \; Q^2 = -q^2, \; \text{and } y = \frac{qp}{kp}$$

Diffractive DIS:

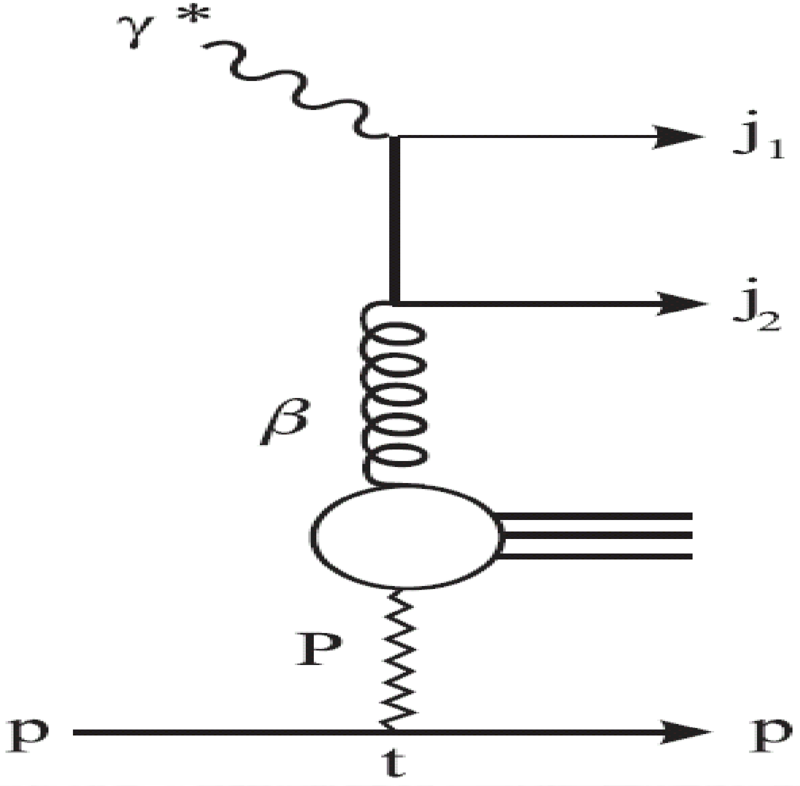
$$M_X^2 = p_X^2 \quad \text{and} \quad t = (p - p_Y)^2,$$
$$M_Y^2 = p_Y^2 \quad \text{and} \quad x_{I\!P} = \frac{q(p-p_Y)}{qp}$$

Experimental cuts:

0.3	$<$	y	$<$	0.65
		Q^2	$<$	$0.01\ \text{GeV}^2$
		E_T^{jet1}	$>$	$5\ \text{GeV}$
		E_T^{jet2}	$>$	$4\ \text{GeV}$
-1	$<$	$\eta_{\text{lab}}^{\text{jet1,2}}$	$<$	2
		$x_{I\!P}$	$<$	0.03
		M_Y	$<$	$1.6\ \text{GeV}$
		$-t$	$<$	$1\ \text{GeV}^2$

Diffractive Parton Distributions

Double factorization:



G. Ingelman, P. Schlein, PLB 152 (1985) 256

Hard QCD factorization:

$$\frac{d^2\sigma}{dx_{I\!P}dt} = \sum_a \int_x^{x_{I\!P}} d\xi \sigma_a^{\gamma^*}(x, Q^2, \xi) f_a^D(\xi, Q^2; x_{I\!P}, t)$$

Regge factorization:

$$f_a^D(x, Q^2; x_{I\!P}, t) = f_{I\!P/p}(x_{I\!P}, t) f_{a/I\!P}(\beta = x/x_{I\!P}, Q^2)$$

Pomeron flux factor:

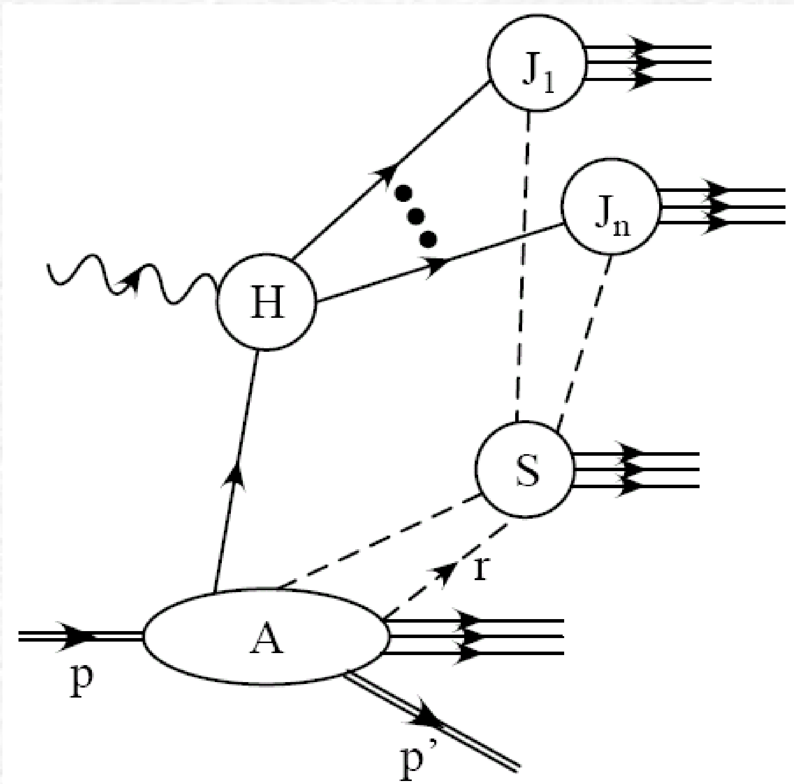
$$f_{I\!P/p}(x_{I\!P}, t) = x_{I\!P}^{1-2\alpha_{I\!P}(t)} \exp(B_{I\!P} t)$$

Pomeron tracectory:

$$\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$$

Proof of Hard Factorization

Diffractive deep inelastic scattering:



J.C. Collins, PRD 57 (1998) 3051

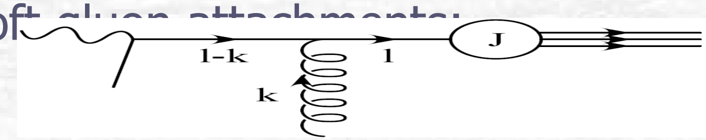
Light cone coordinates:

- $q^\mu = (q^+, q^-, \mathbf{q}_T)$

Leading regions:

- H: $q^\mu \approx O(Q)$
- J: $l^\mu \approx (0, Q/\sqrt{2}, \mathbf{0}_T)$
- A: $|k^\mu| \ll O(Q)$

Soft gluon attachments:

- 

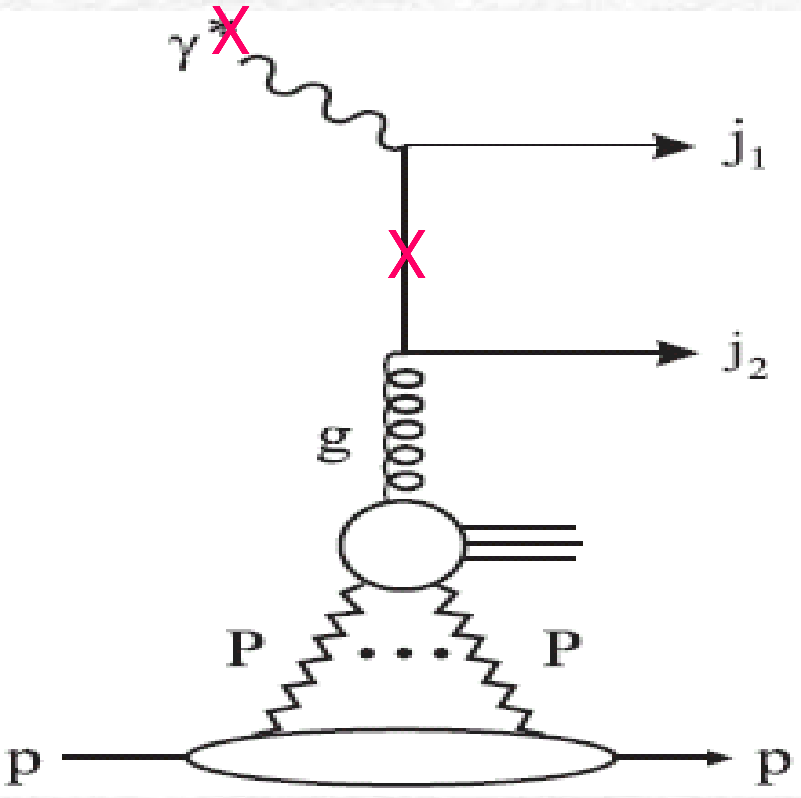
- $$\frac{1}{(l-k)^2 - m^2 + i\epsilon} \simeq \frac{1}{-2l^-k^+ + \text{transverse} + i\epsilon}$$

Poles in k^+-plane:

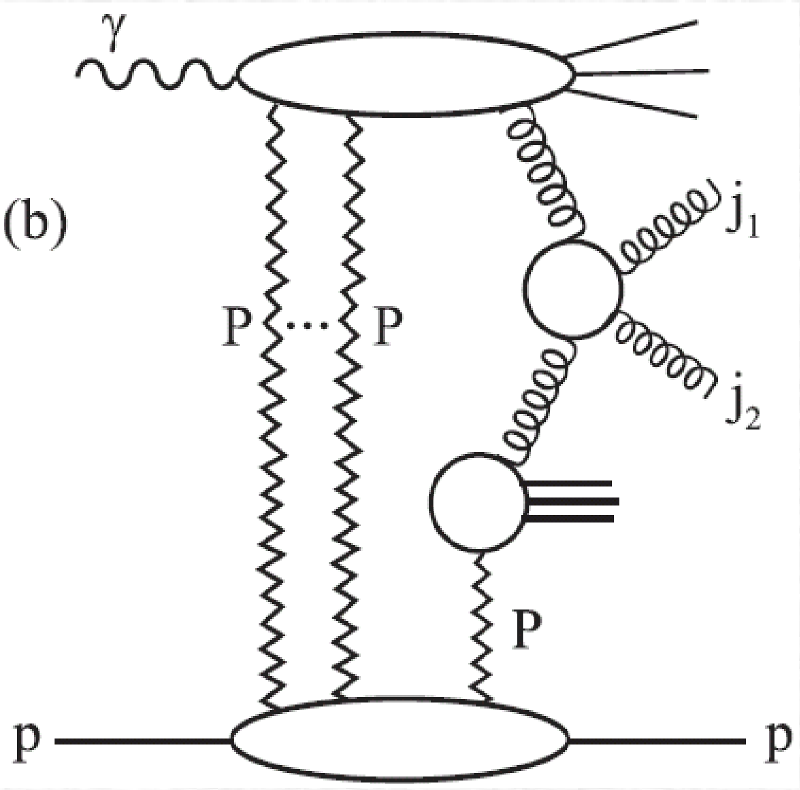
- Final state: Upper half-plane
- Initial state: Lower half-plane

Multipomeron Exchanges

Direct photoproduction:



Resolved photoproduction:



→ Modify the Regge trajectory

→ Factorization breaking

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Diffractive Photoproduction of Dijets

Cross section:

$$d\sigma^D(ep \to e + 2\ \text{jets} + X' + Y) =$$
$$\sum_{a,b} \int_{t_{\rm cut}}^{t_{\rm min}} dt \int_{x_{I\!P}^{\rm min}}^{x_{I\!P}^{\rm max}} dx_{I\!P} \int_0^1 dz_{I\!P} \int_{y_{\rm min}}^{y_{\rm max}} dy \int_0^1 dx_\gamma$$
$$f_{\gamma/e}(y) f_{a/\gamma}(x_\gamma, M_\gamma^2) f_{I\!P/p}(x_{I\!P}, t) f_{b/I\!P}(z_{I\!P}, M_{I\!P}^2)$$
$$d\sigma^{(n)}(ab \to \text{jets}).$$

Photon flux: Weizsäcker-Williams approximation

$$f_{\gamma/e}(y) = \frac{\alpha}{2\pi}\left[\frac{1+(1-y)^2}{y}\ln\frac{Q^2_{\rm max}(1-y)}{m_e^2 y^2} + 2m_e^2 y\left(\frac{1-y}{m_e^2 y^2} - \frac{1}{Q^2_{\rm max}}\right)\right]$$

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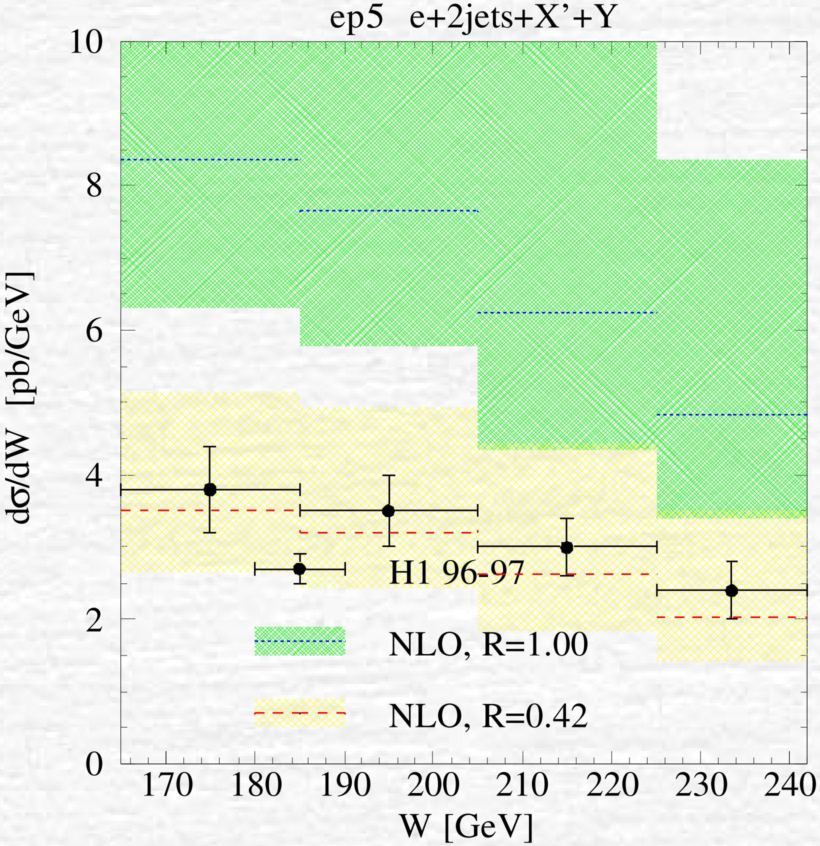
Diffractice parton distributions (DPDFs)

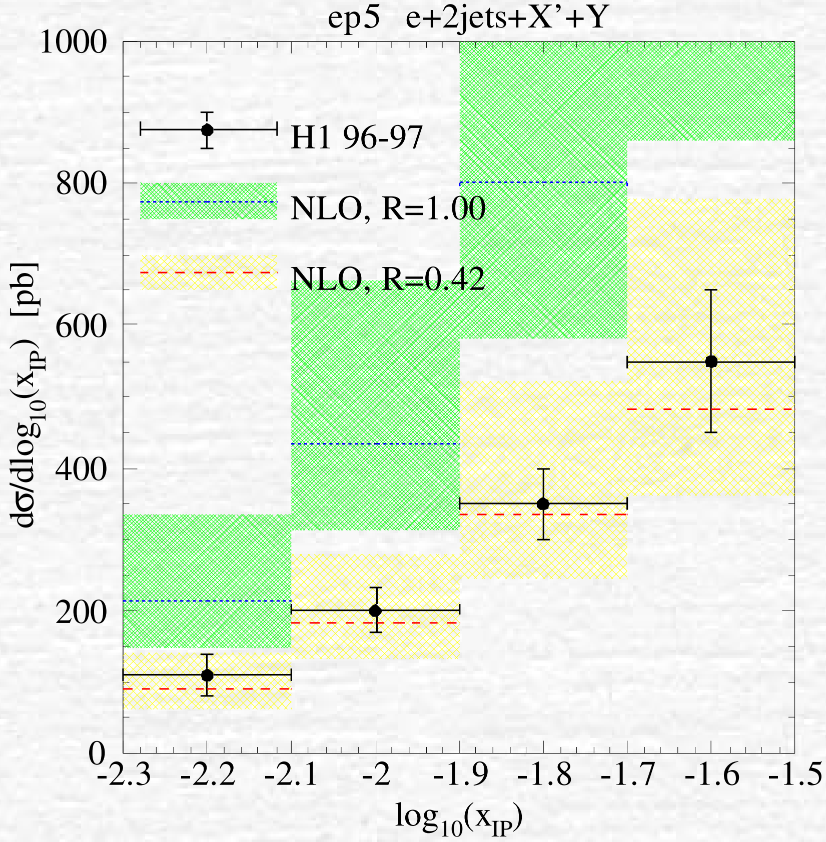
- DPDFS from diffractive DIS measurements of F_2^D:
-
- H1 Coll., A. Aktas et al., Eur. Phys. J C 48 (2006) 715
- H1 2006 fit A and H1 2006 fit B, both M_Y < 1.6 GeV
- H1 Coll., A. Aktas et a., JHEP 10 (2007) 042
- H1 2007 fit jets
- ZEUS Coll., S. Chekanov et al., Eur. Phys. J. C38 (2004) 43
- ZEUS LPS fit, measurement for ep -->e'pX, only
- proton, no additional proton dissociation in final state

Factorization Breakink at NLO

- W-depend.:photon flux



- x||P-depend.:Pomeron fl



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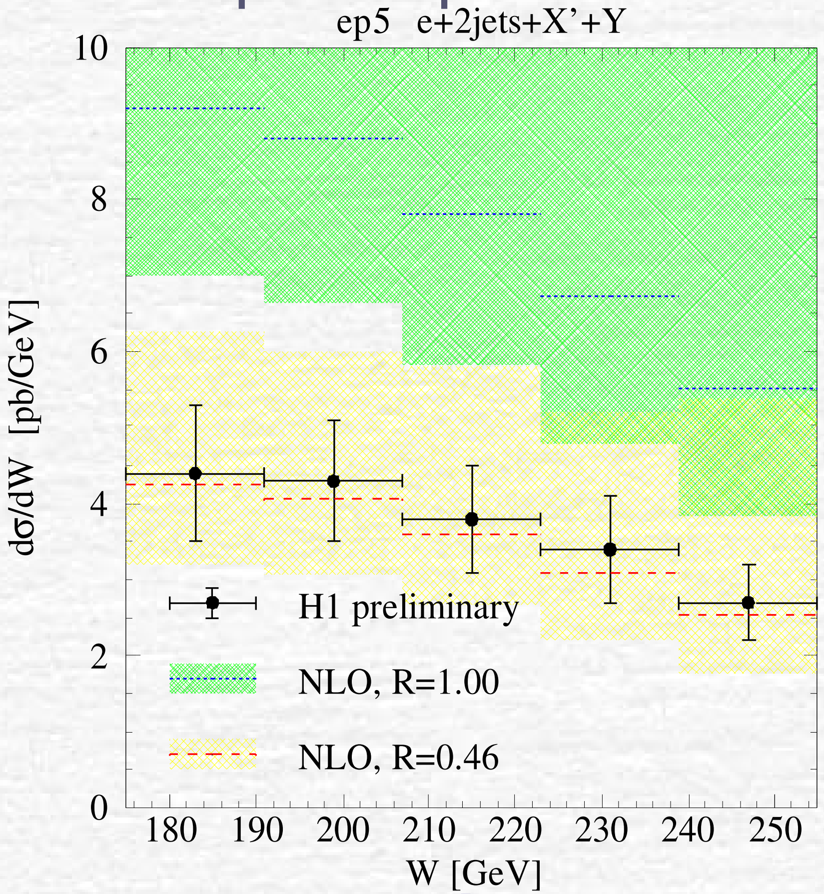
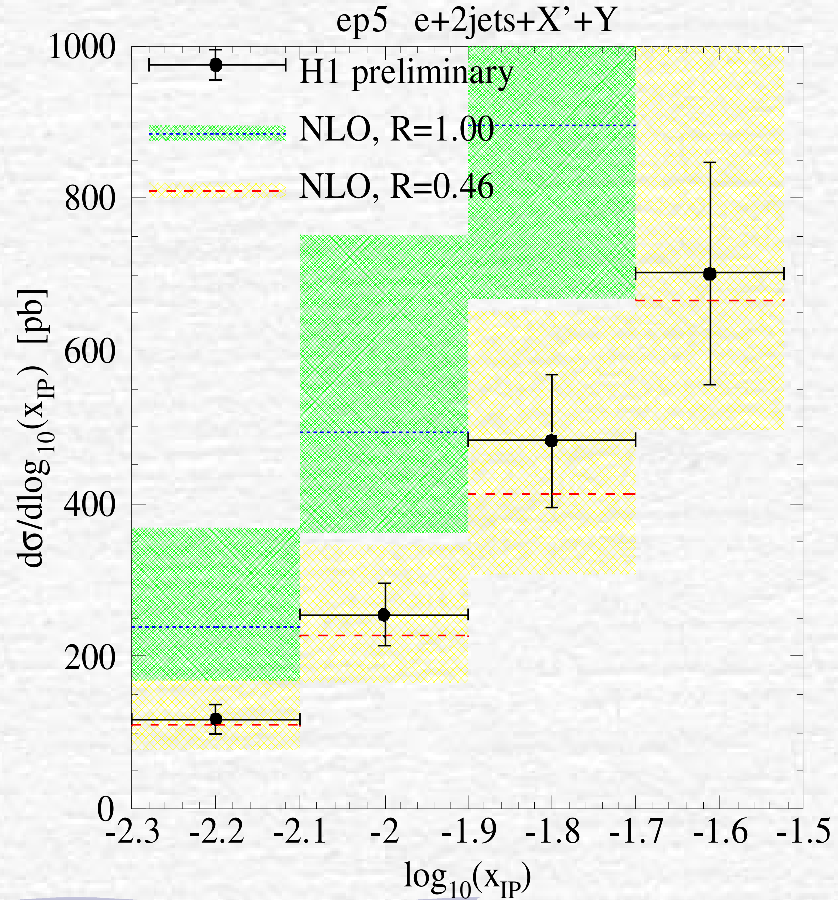
Factorization Breaking at NLO

- W depend.: photon flux

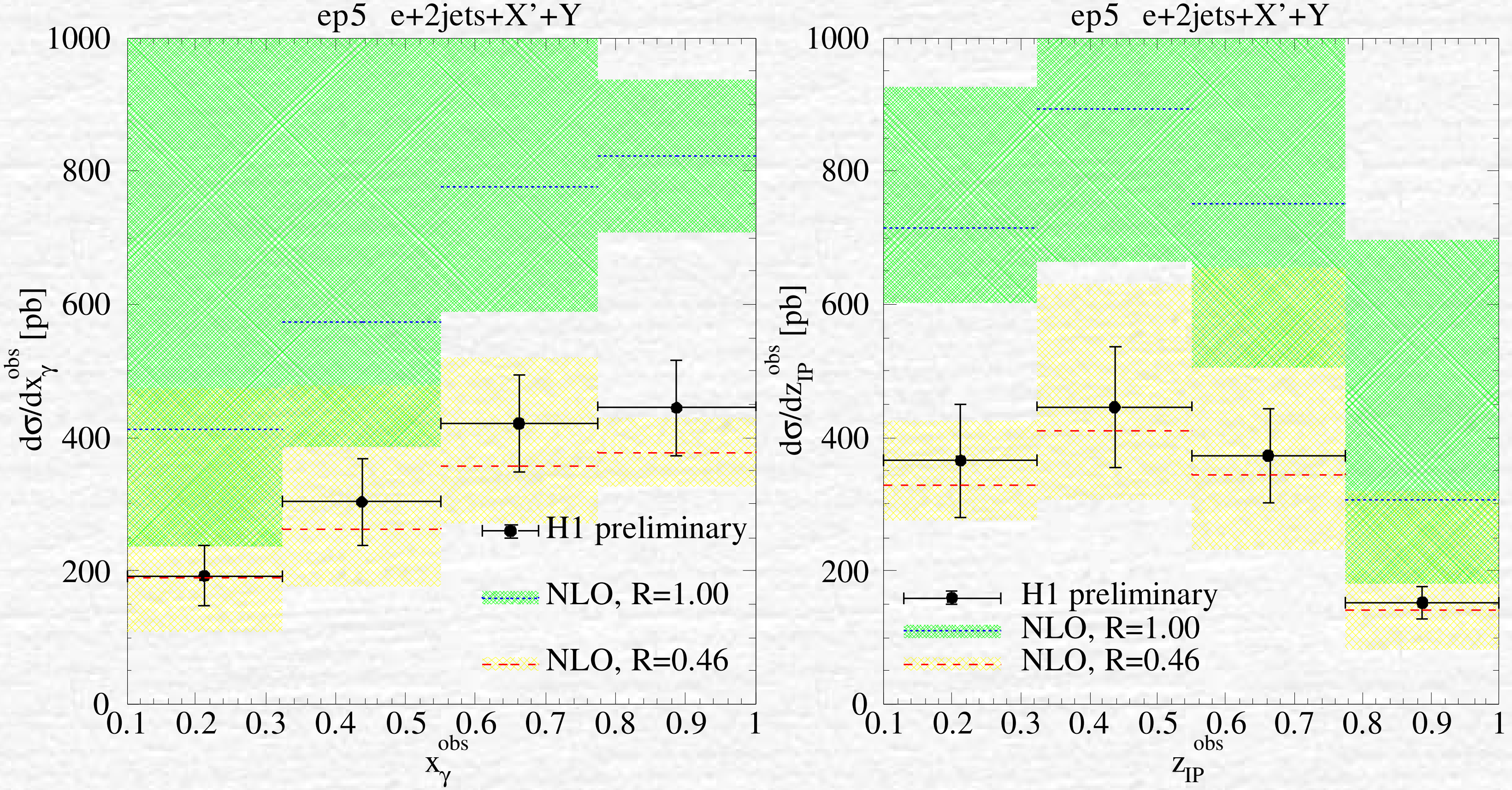


- x||P depend.: pom. flux



Factorization Breaking at NLO

- xgam-depend.,dir./resolv
- z||Pdepend.,gluoninpom.



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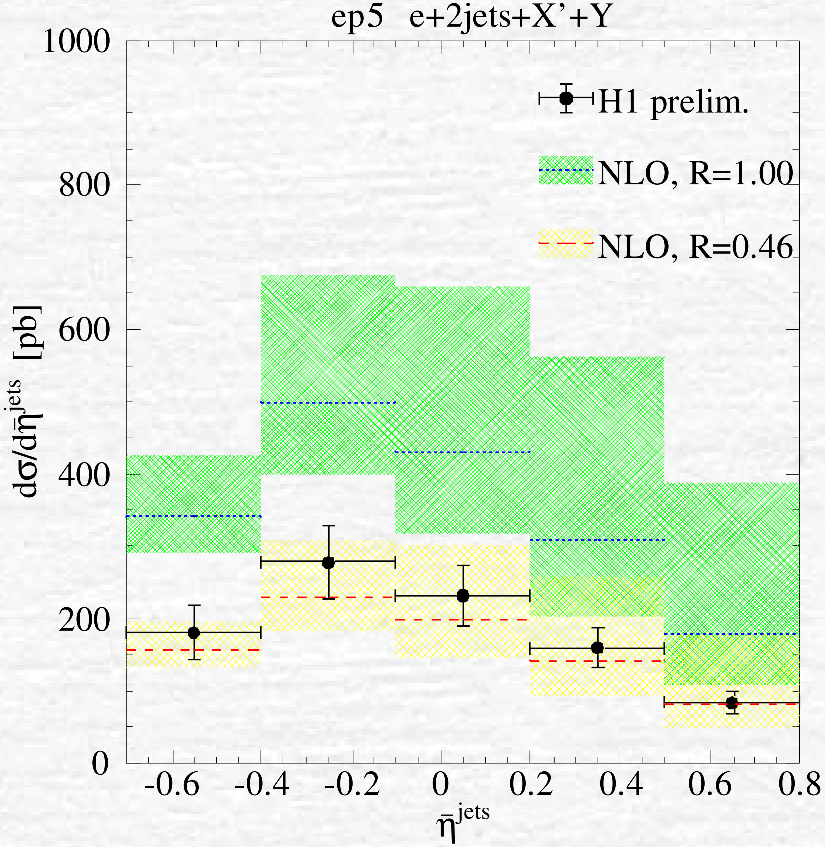
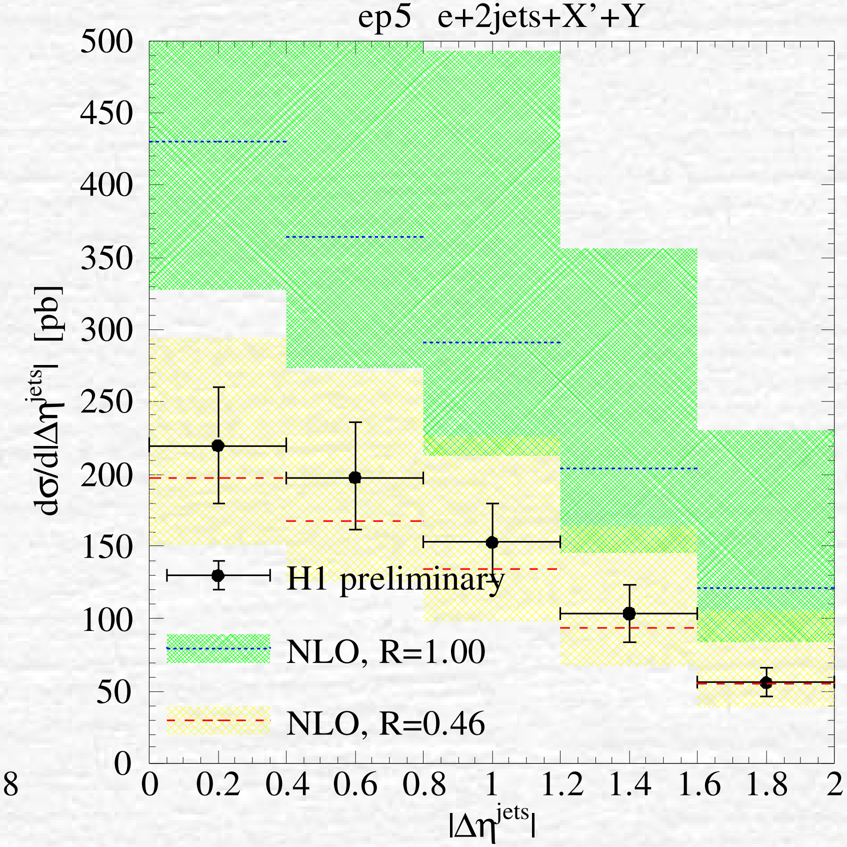
Factorization Breaking in NLO

- eta^jets-dependence
- Delta eta^jets-depend.





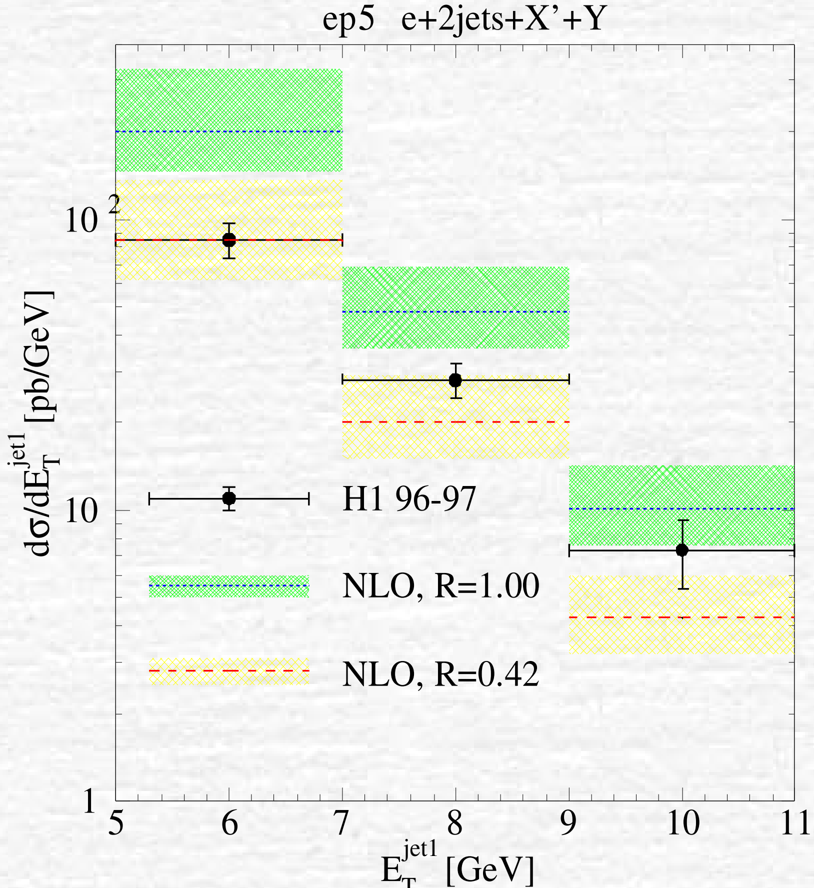
E_T-Distribution

Importance of large E_T:

- Direct process dominates
- IS singularity less important
- Hadronization corrections small
- Experimentally directly accessible
- Less sensitive than xγ

Result:

- Suppressed result fitted at
- Low E_T
- Unsuppressed 50% too low
- for low E_T
- Suppression less at high E_T



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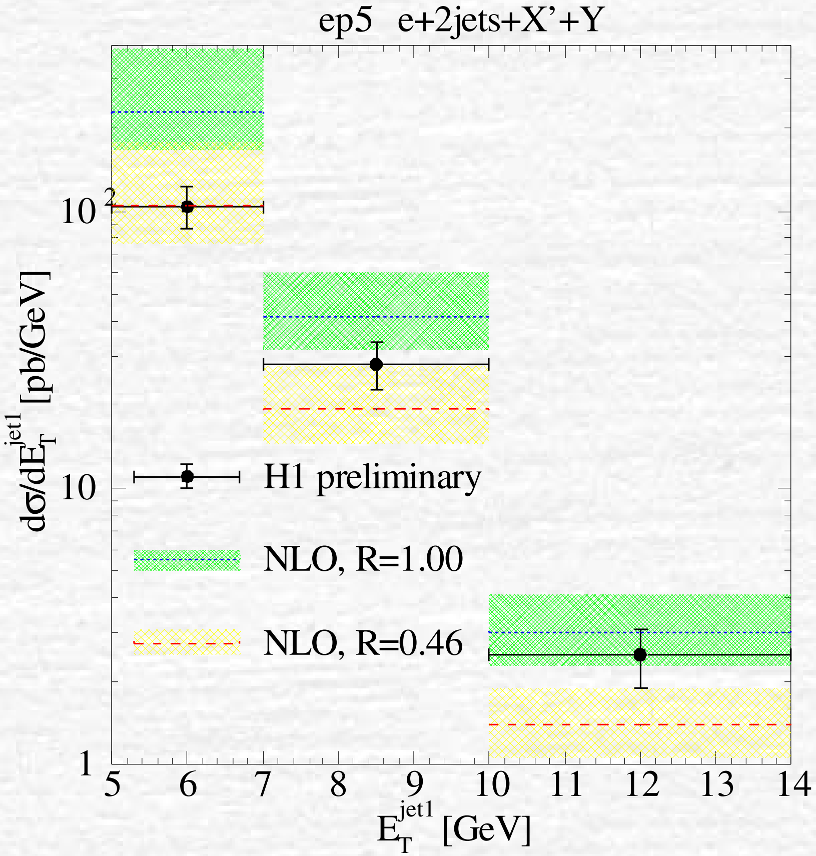
E_T-distribution for preliminary data

- Fit to low E_T bin



- Largest E_T-bin
- fitted better with R=1
- (unsuppressed)
- resolved suppression only should fit better

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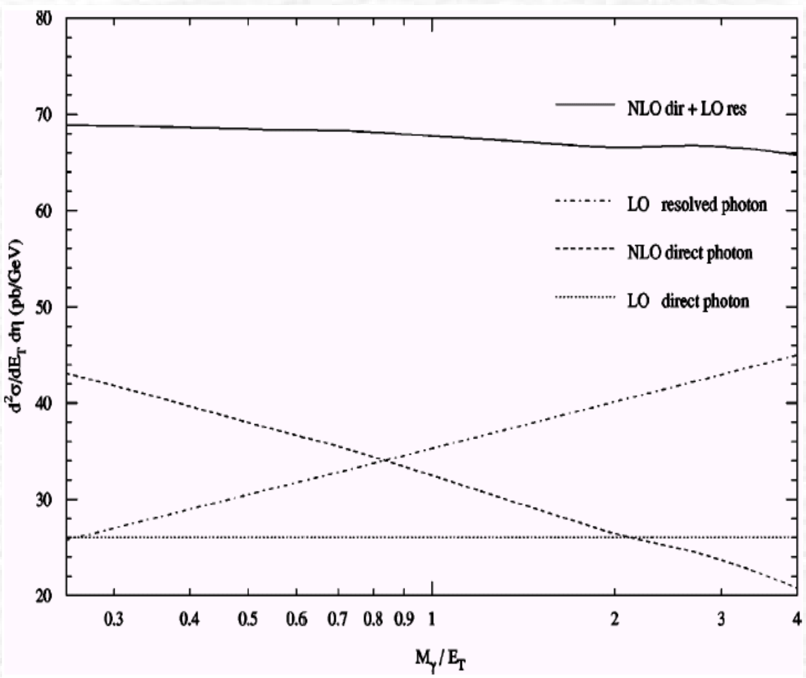
Factorization Scale Dependence

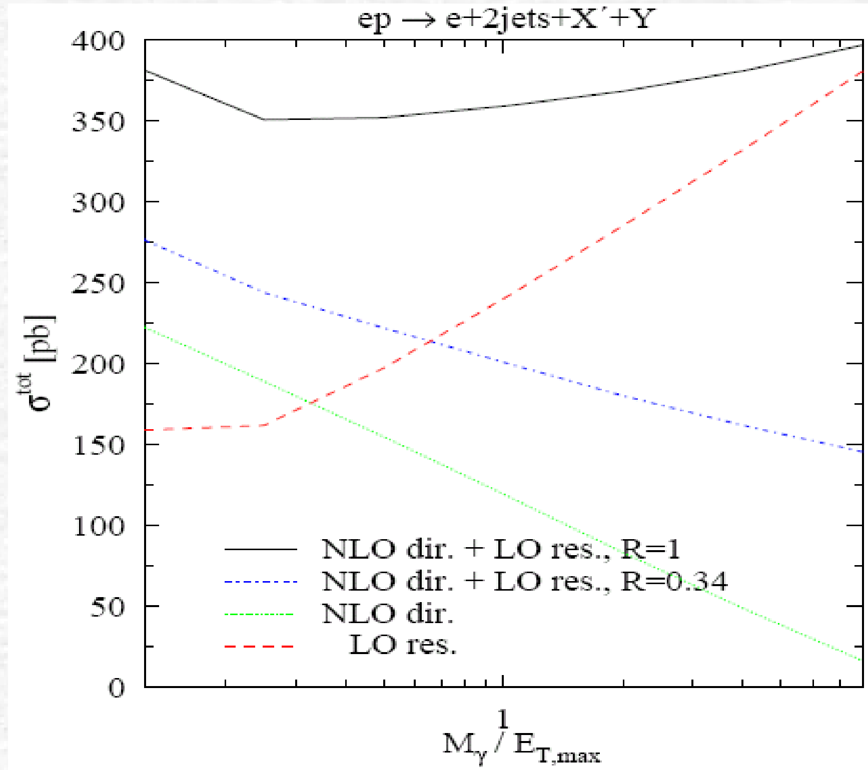
Inclusive photoproduction:

$$|\mathcal{M}^I|^2_{ab\to 123} = \ln\left(\frac{M^2}{Q^2}\right)|\mathcal{M}^B|^2_{cb\to 12} P_{c\leftarrow a}(x) + \cdots$$



MK, Rev. Mod. Phys. 74 (2002) 1221

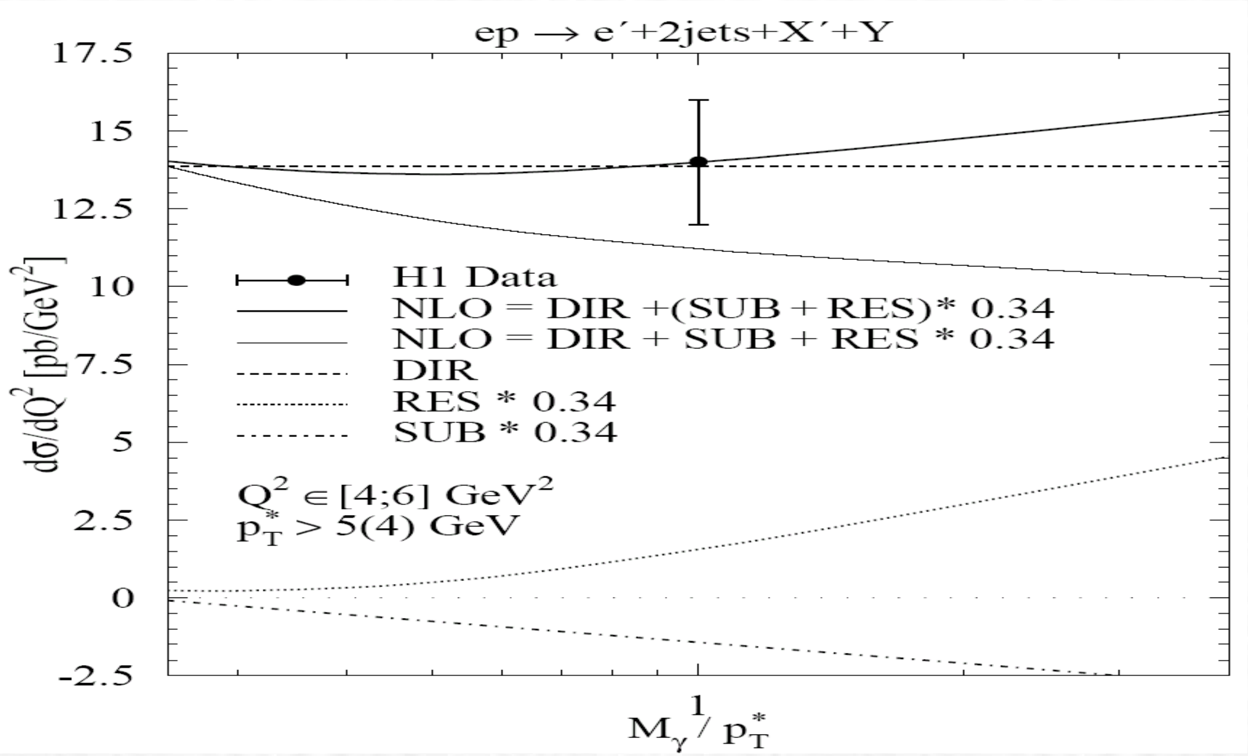
Diffractive photoproduction:



M. Klasen, G. K., EPJC 38 (2004)39

Factorization Scale Dependence (1)

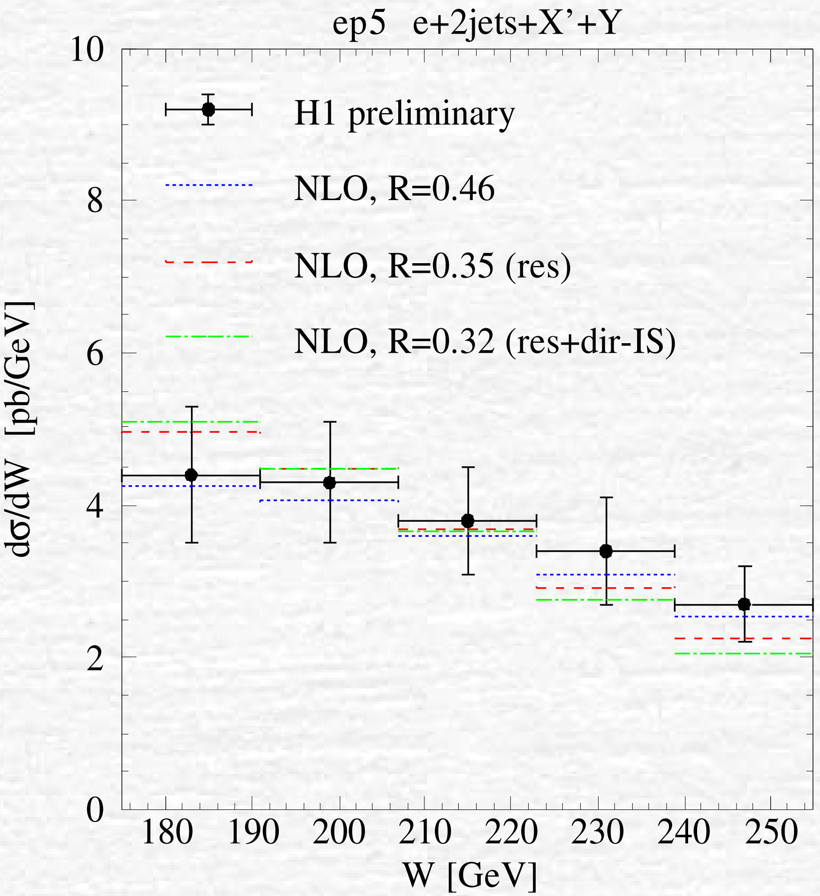
$$M(P^2)_{\overline{MS}} = -\frac{1}{2N_c} P_{q_i \leftarrow \gamma}(z_a) \ln\left(\frac{M_\gamma^2 z_a}{(z_a P^2 + y_s s)(1-z_a)}\right) + \frac{Q_i^2}{2}$$



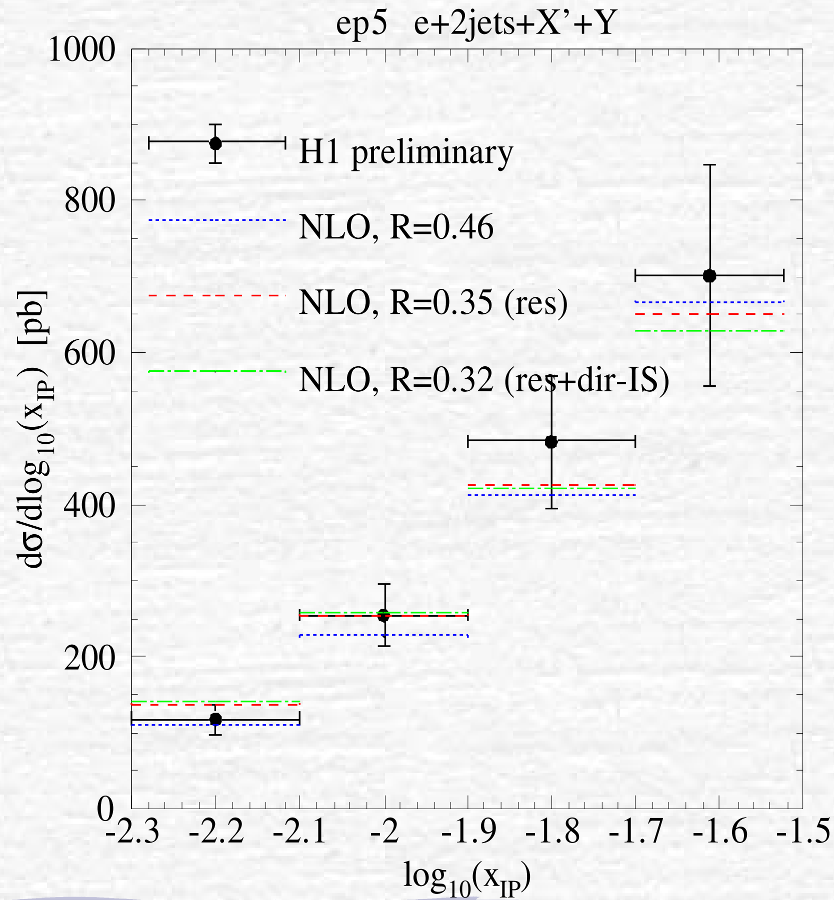
Michael Klasen , G. K., JPG 31 (2005) 1391

Breaking in resolved/resoved/direct-IS

- W-dependence:Photon fl.

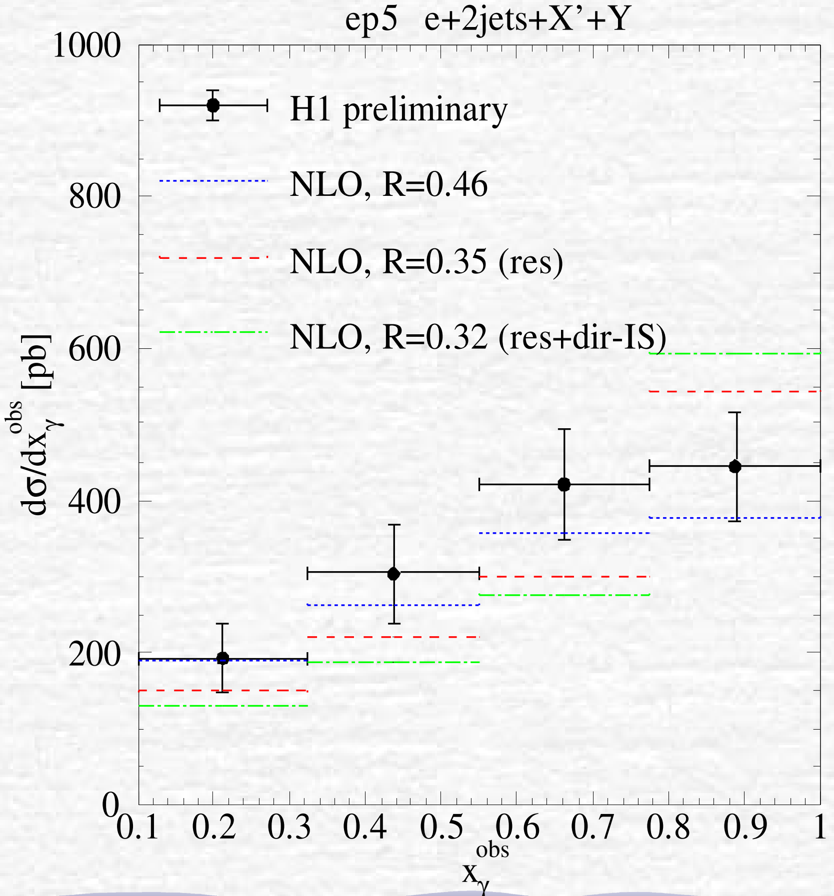


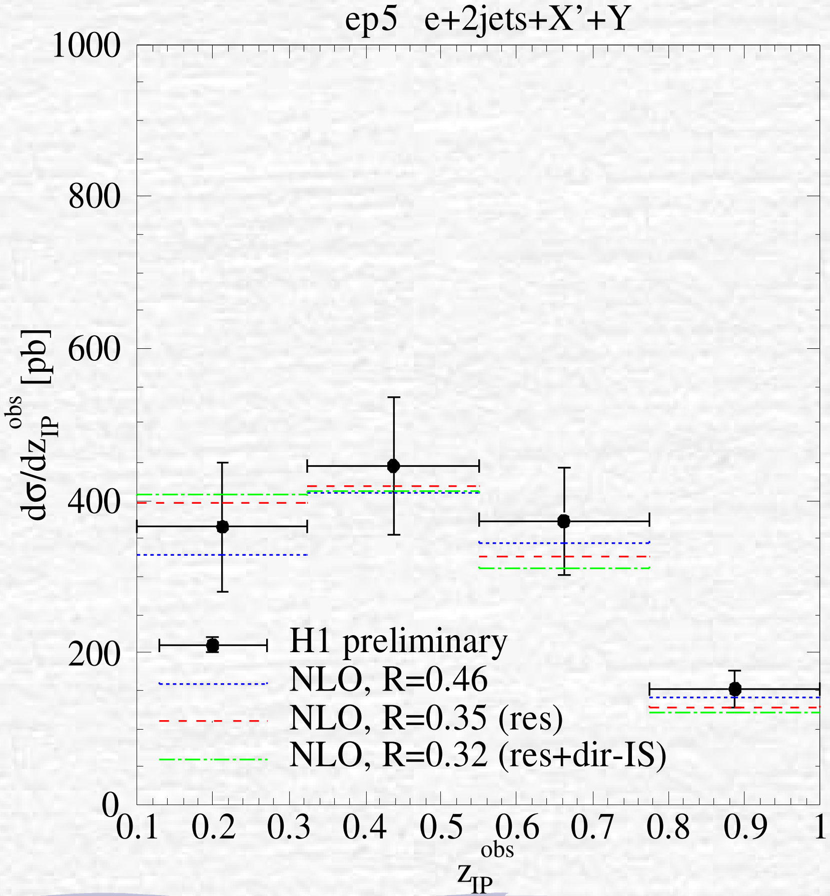
- x||P-dependence:Pom. fl.



Breaking in resolved or resolved/direct-IS

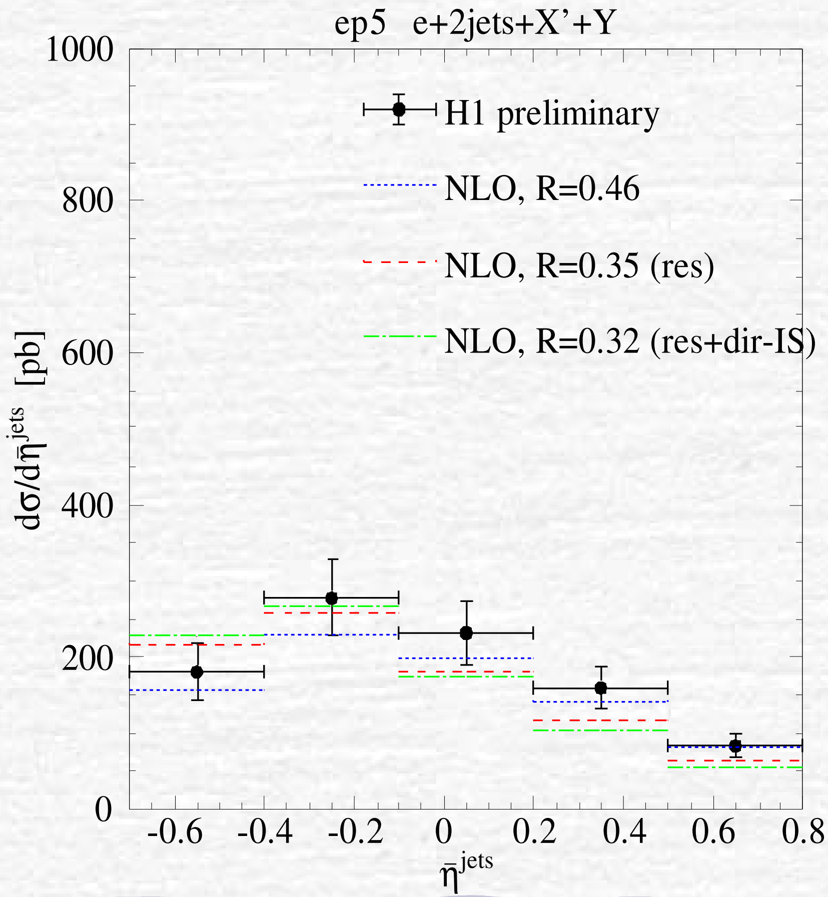
- xgam-depend.:direct/res.
- z||P-depend.:gluon in |P

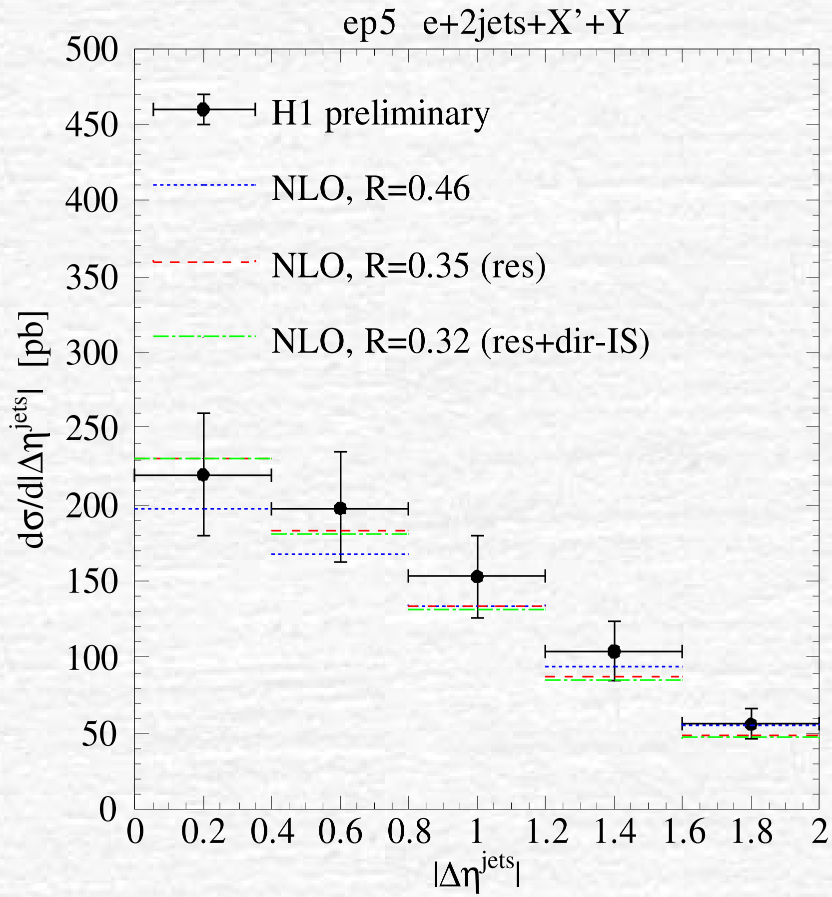




Breaking in resolved or resolved/direct_IS

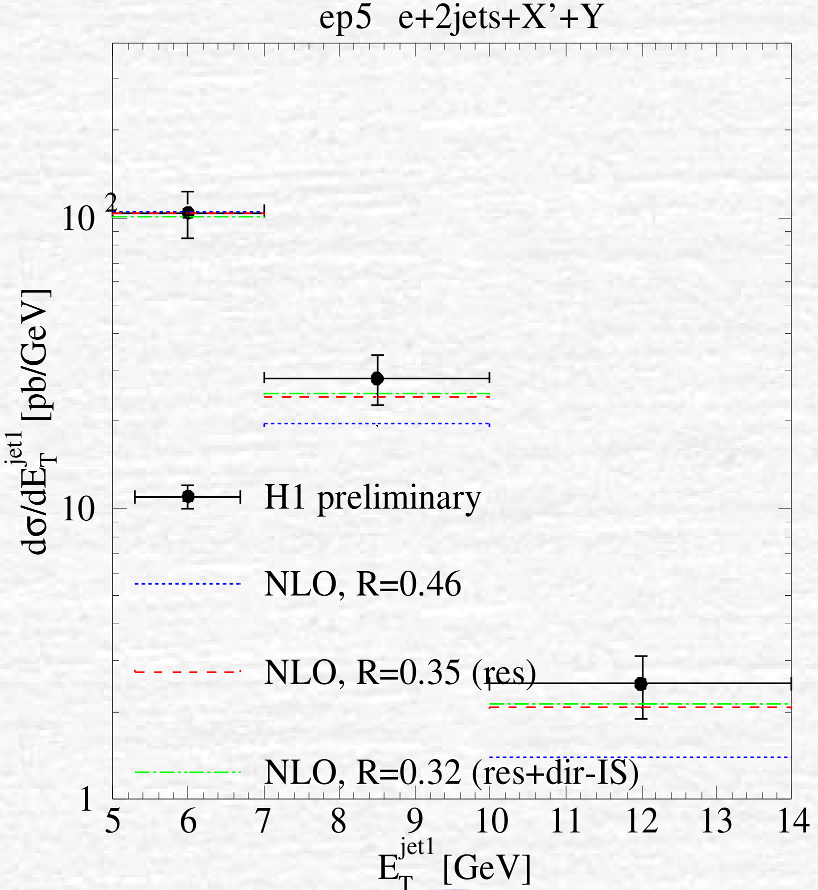
- eta^{jets}-dependence
- Delta eta^{jets}-depend.





Breakind in resolved or resolved/direct-IS

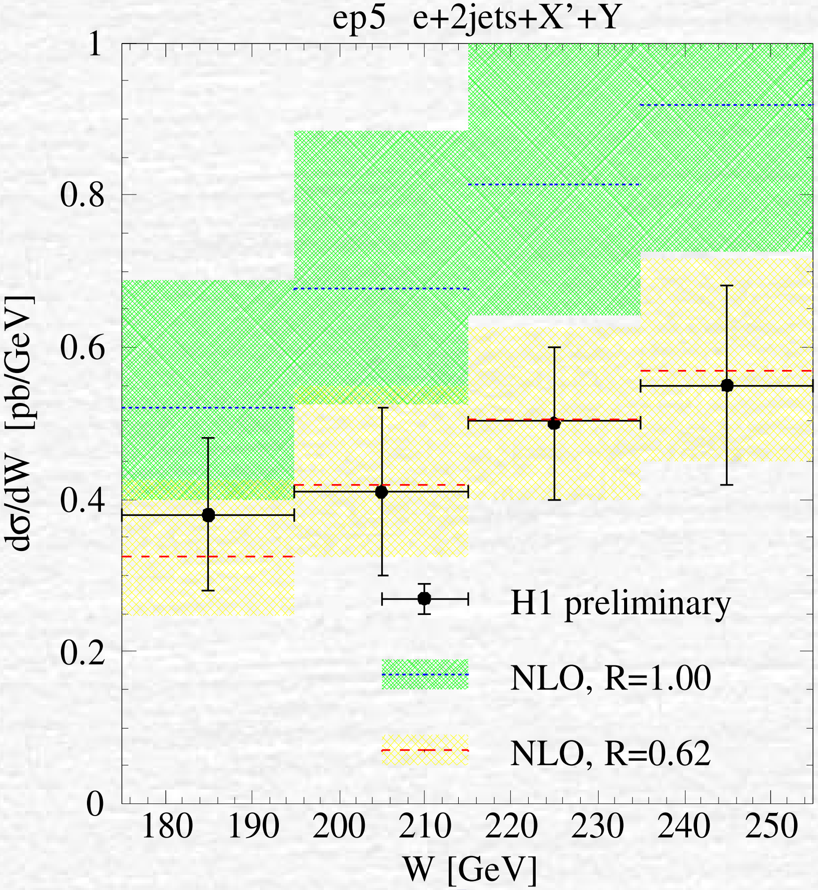
- ET^{jet1}-dependence

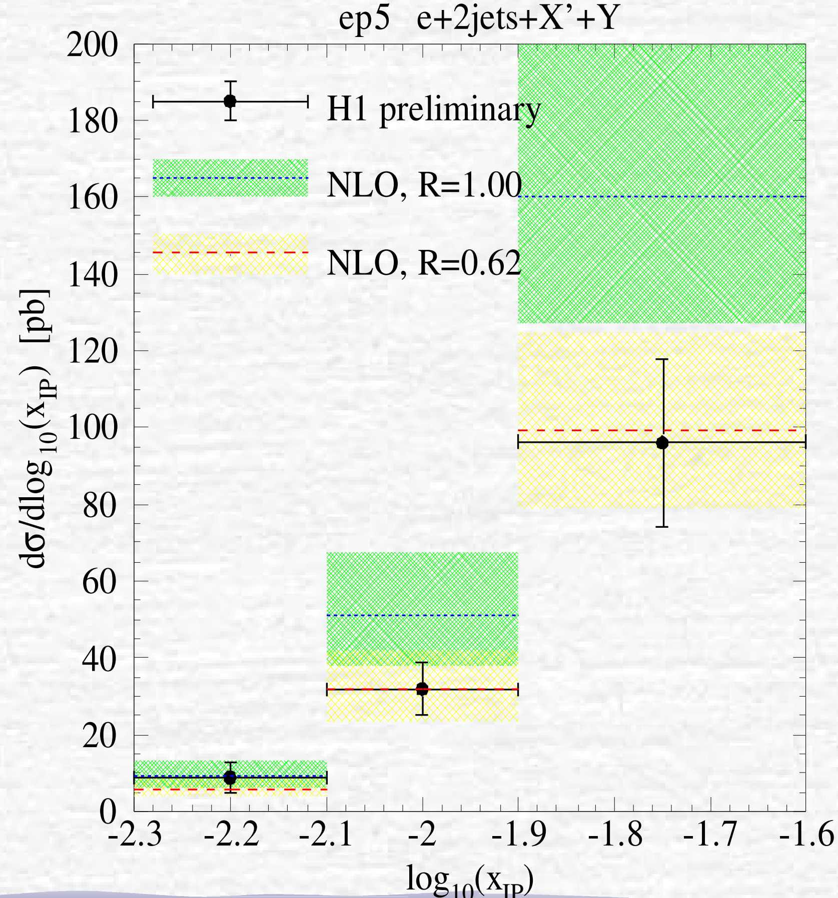


- ET-dependence perfectly
- described by resolved
- and resolved/direct-IS
-
- Supression factors
- slightly different
- R=0.35 (resolved)
- R=0.32 (resolved/direct-
- IS)

Factorization Breaking at NLO, high E_T

- W-depend.: photon flux
- X |P depend.: pom. flux





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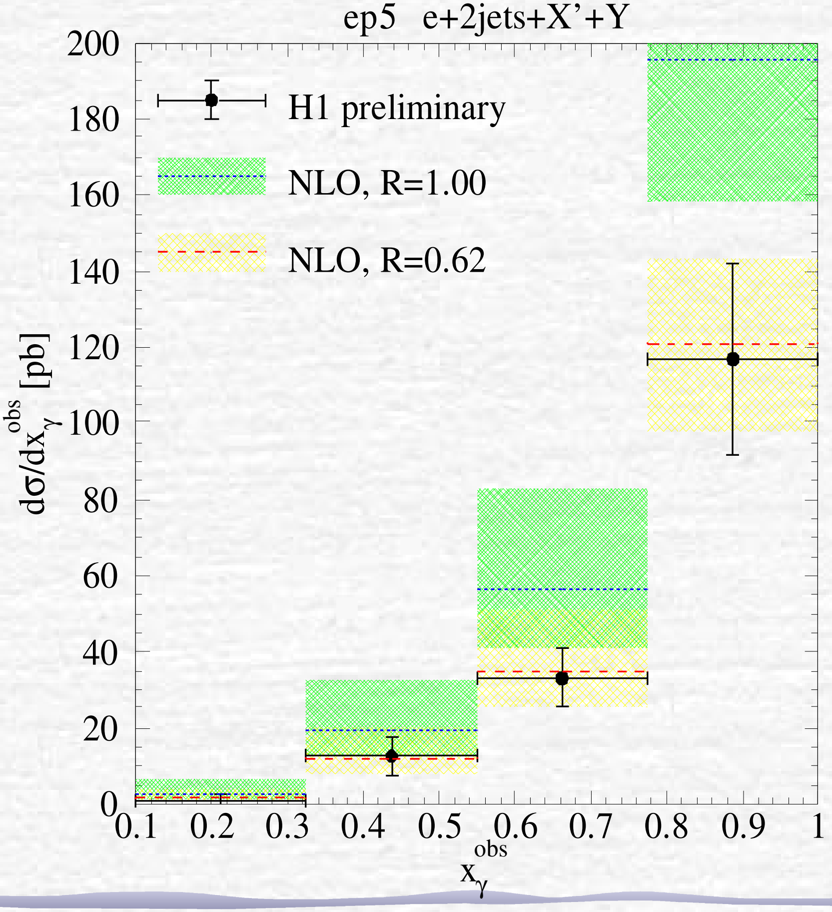
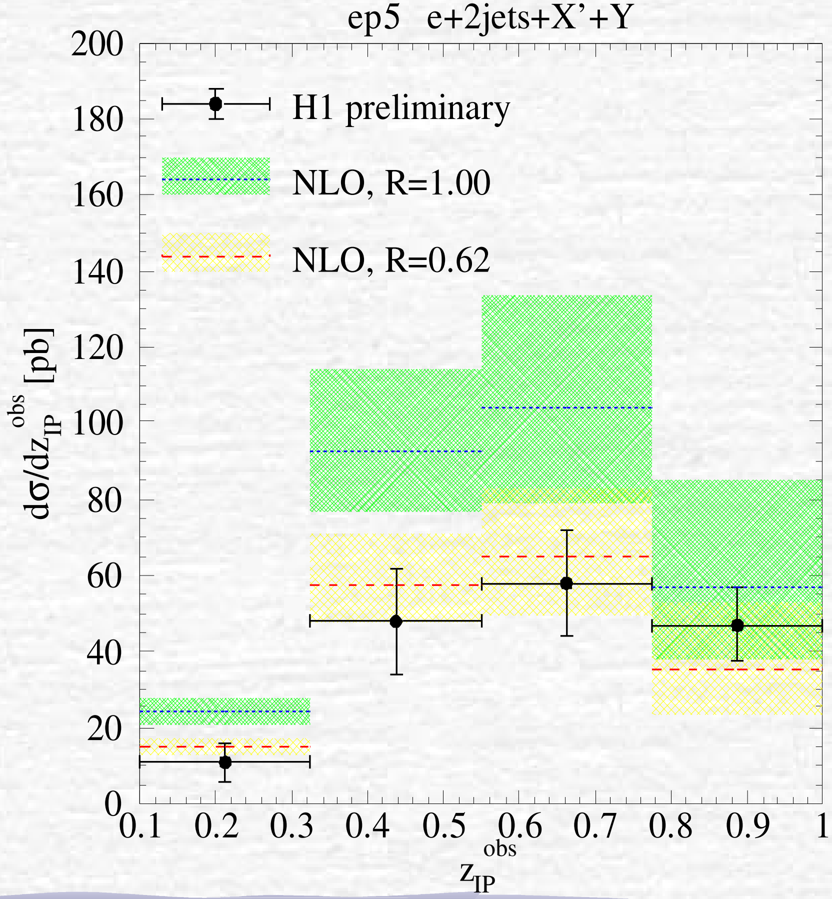
Factorization Breaking at NLO, high E_T

- x_gamma-dependence



- z_|P-dependence



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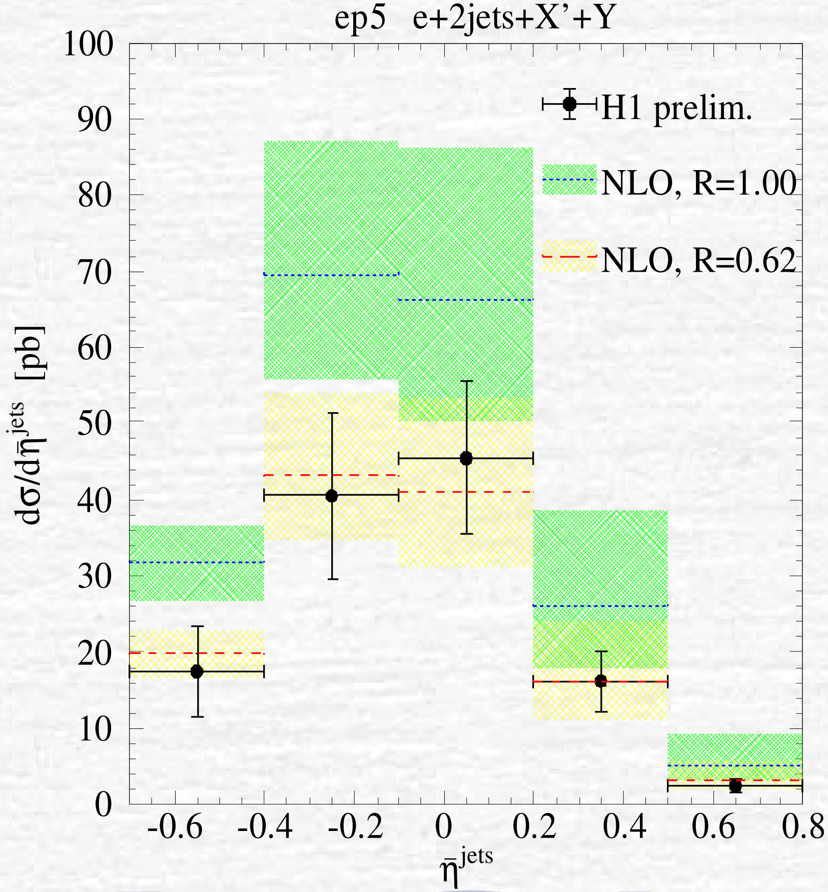
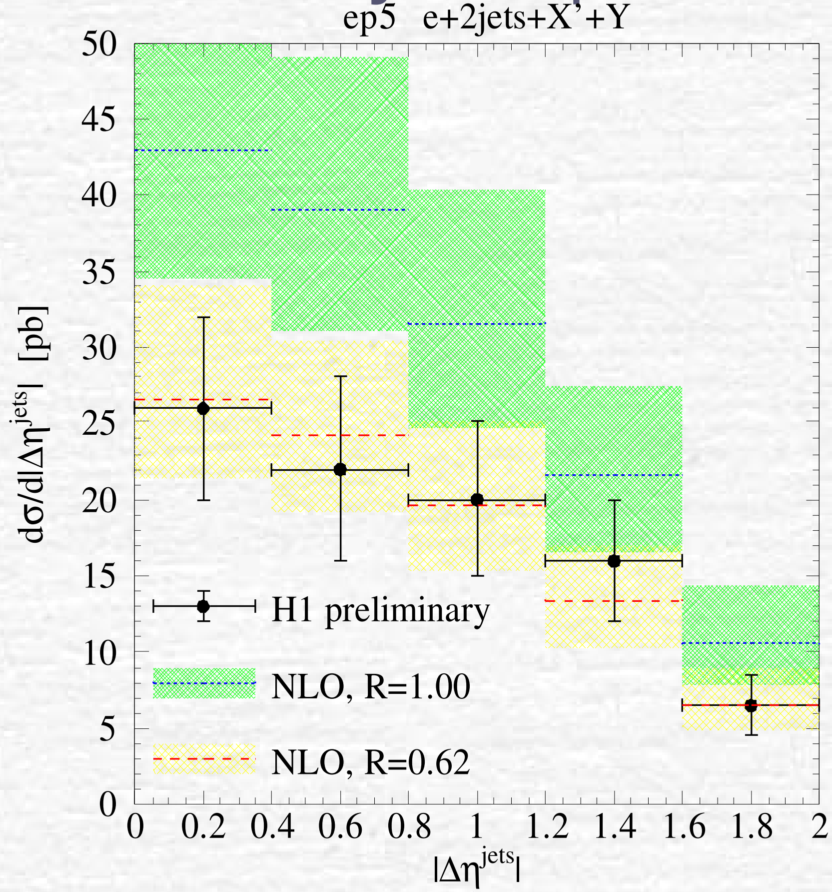
Factorization Breaking, high E_T

- eta^jets-dependence

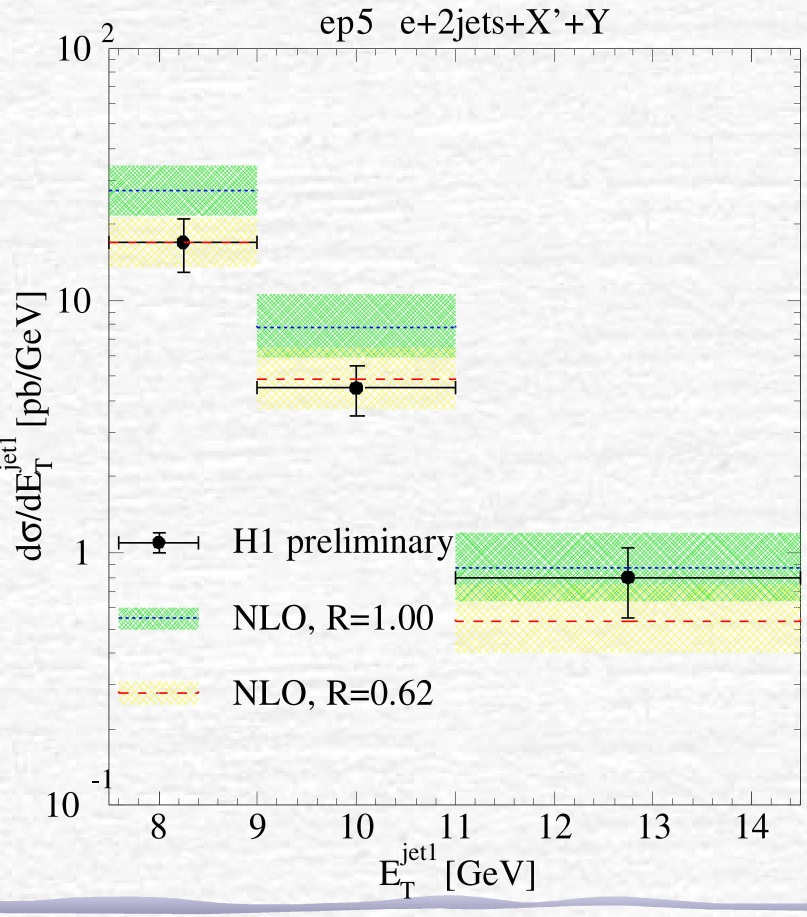


- Delta eta^jets-depend



Factorization Breaking, high E_T

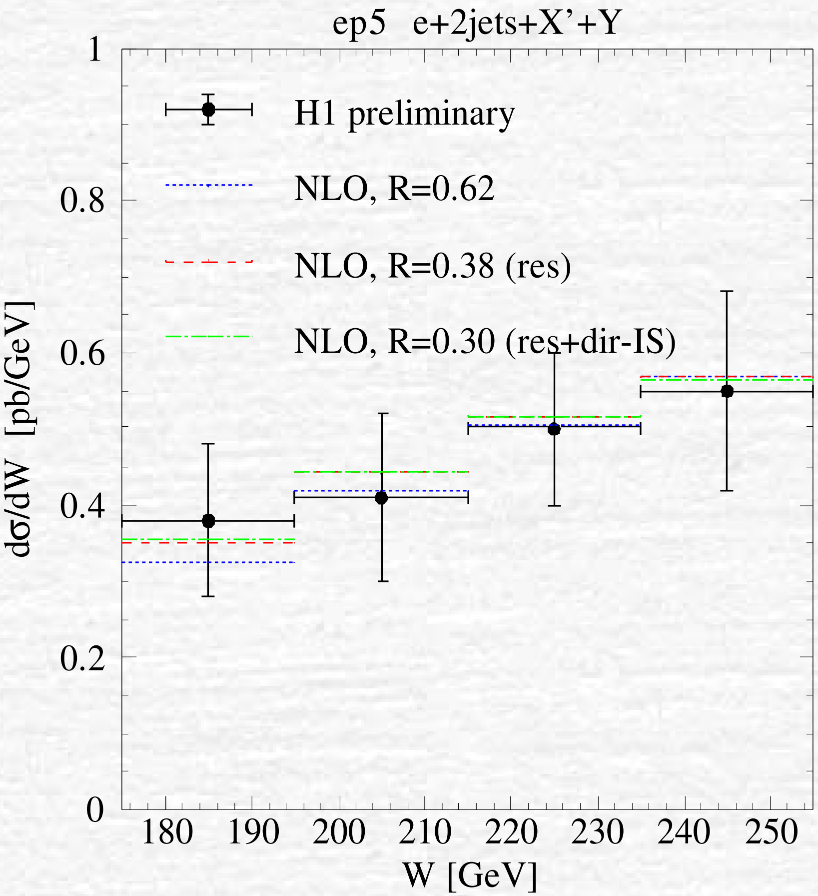
- E_T distribution

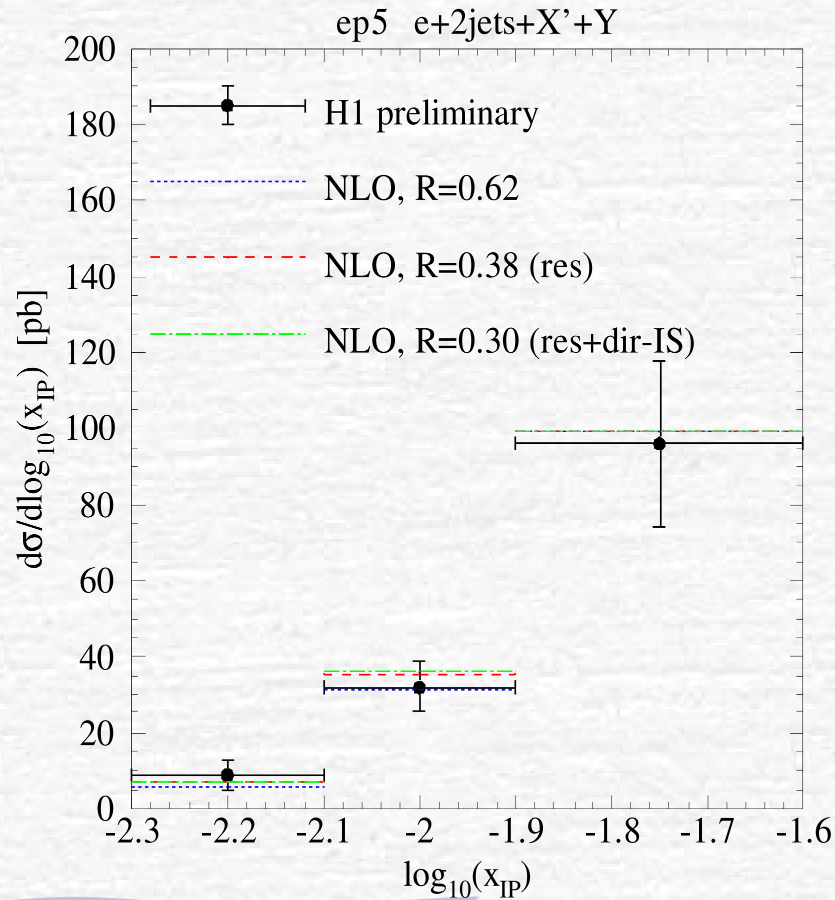


-
- Two lowest E_T bins agree
- Highest E_T bin agrees bettter
- with unsuppressed
- Resolved suppression only would account for
- this

Breaking in resolved or resolved/direct-IS

- W- depend.: photon flux
- x|P-depend.: pomeron fl





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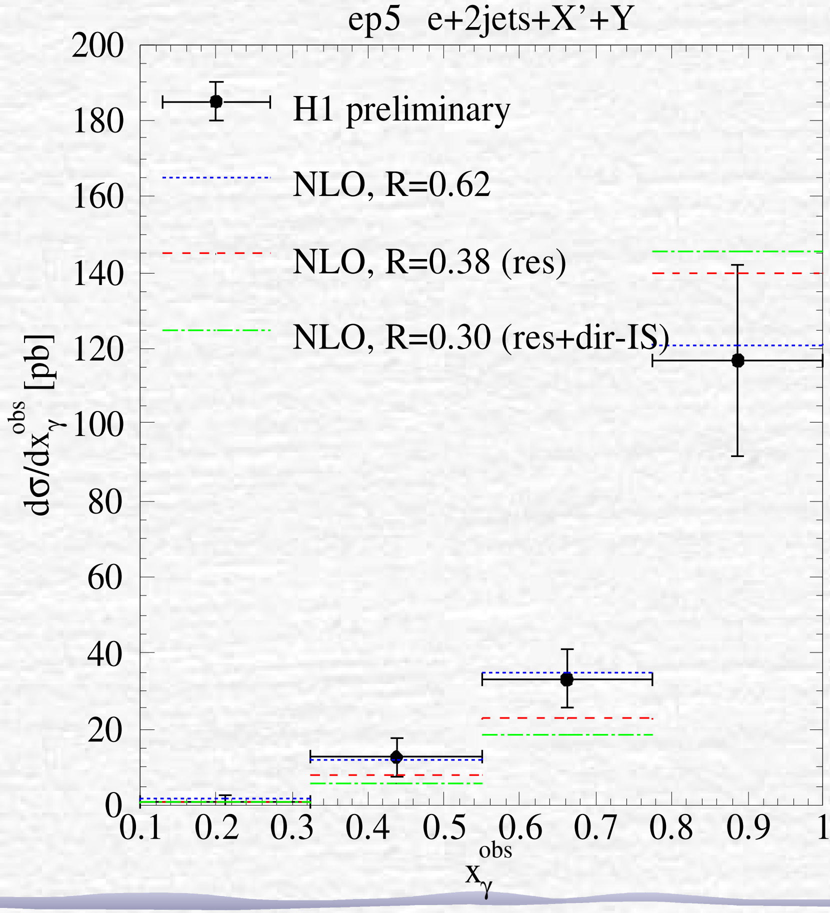
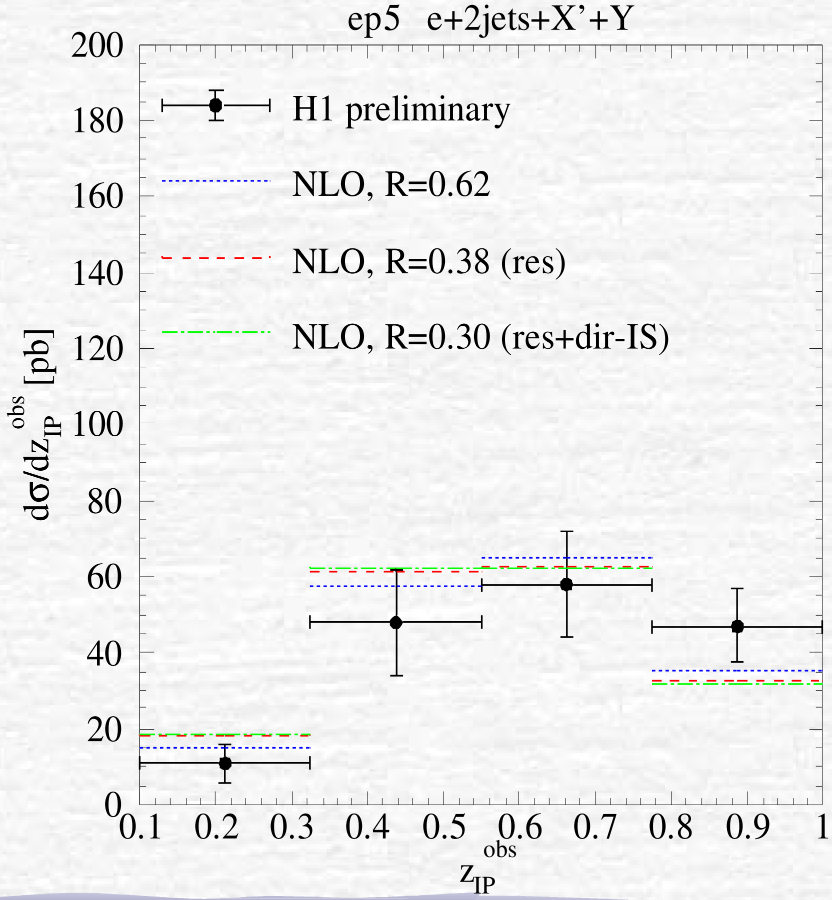
Breaking in resolved or resolve/direct-IS

- x-gamma-dependence



- z_|P-dependence



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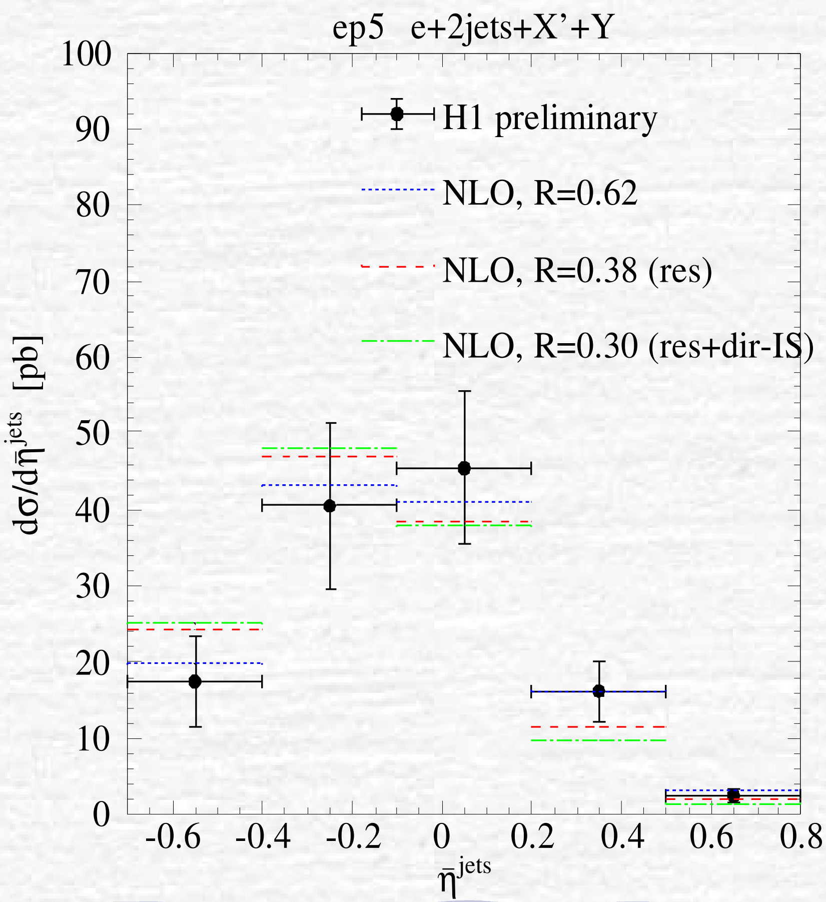
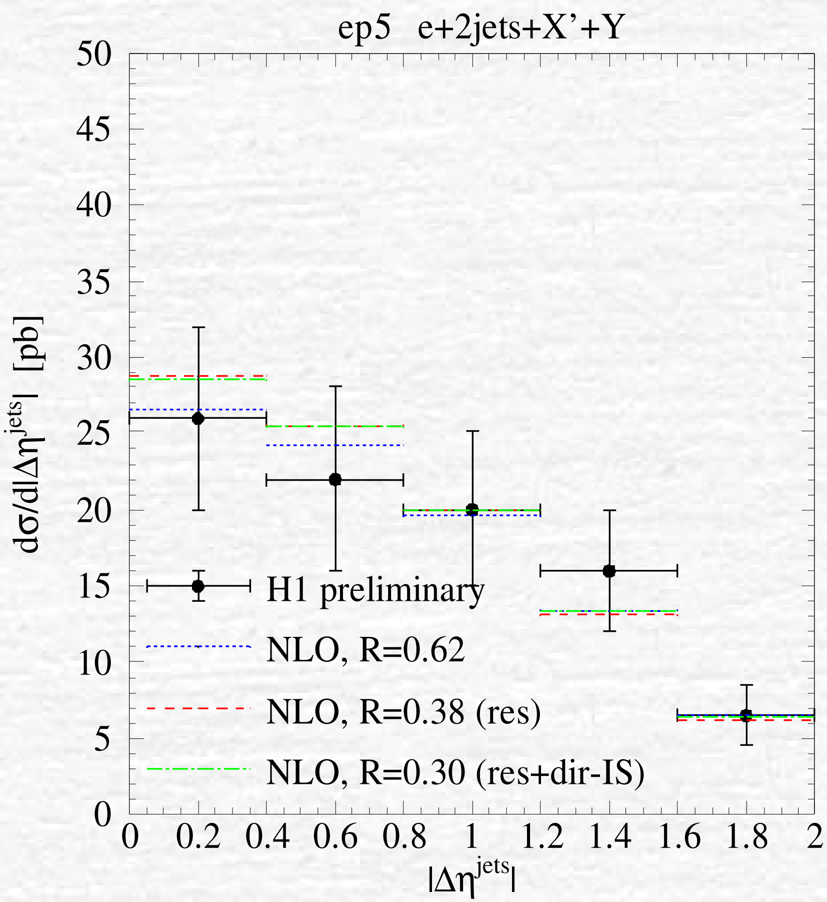
Breaking in resolved or resolved/direct-IS

- eta^jets-dpendence



- Delta eta^jets-depend.



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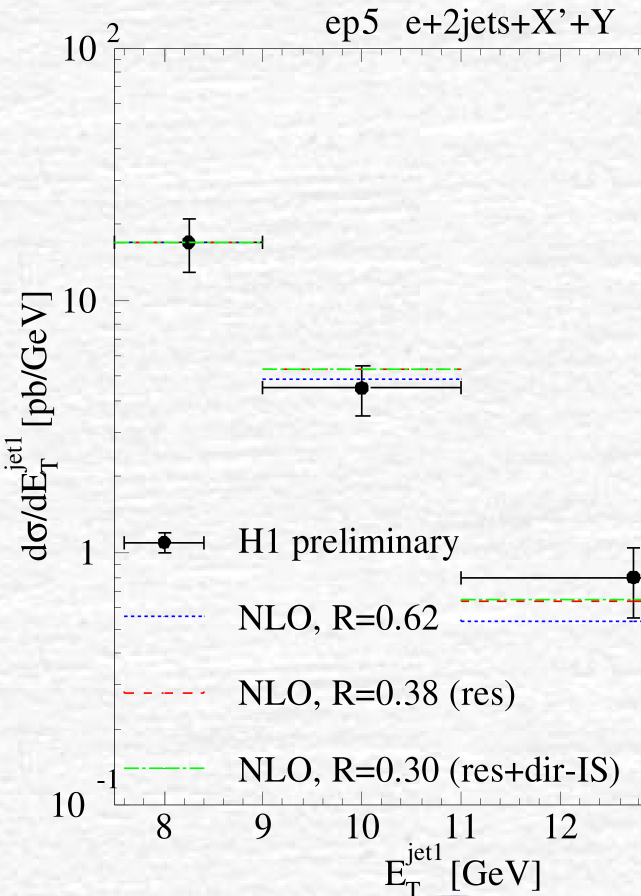
Breaking in resolved or resolved/direct-IS

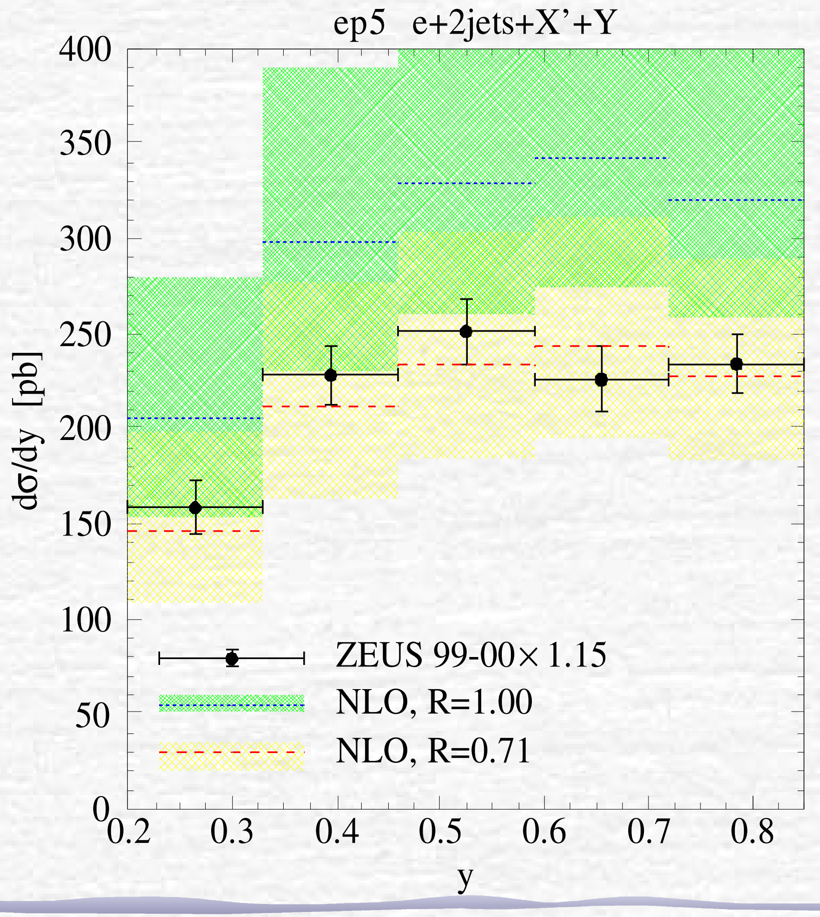
- E_T-dependence



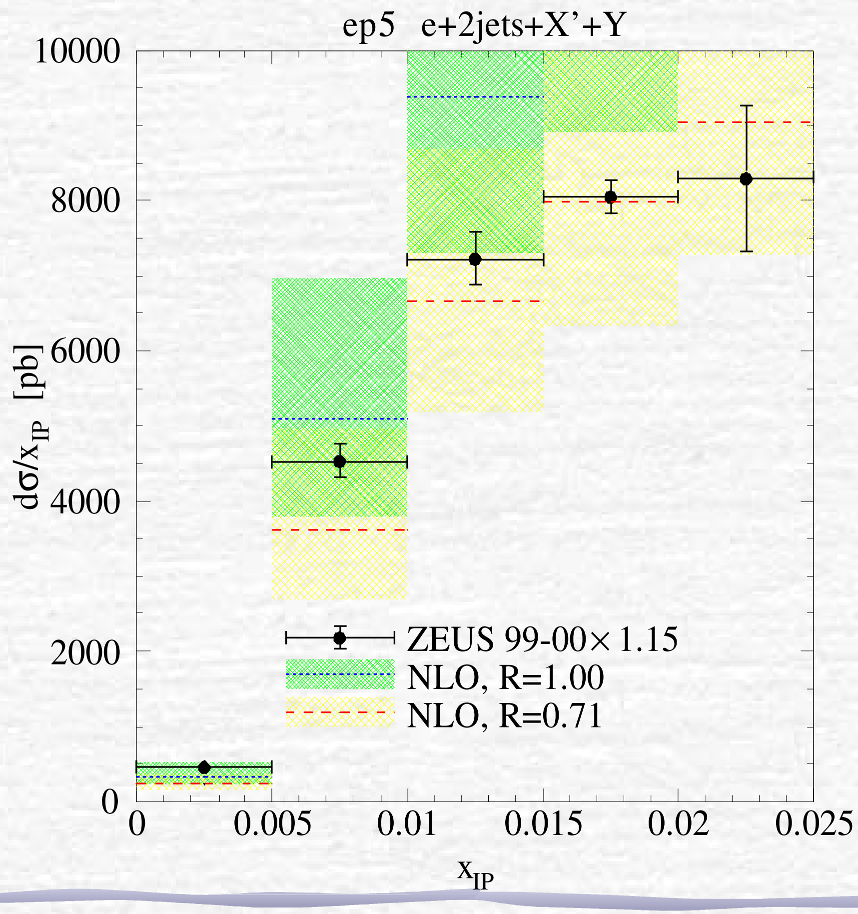
- All three E_T bins
- agree very well
  difference to global suppression not significant
- R=0.62 global suppr.
- R=0.38 resolved supp.
- R=0.32 resolved/direct_IS supp.

Factorization Breaking at NLO

- y-dependence:Photon fl.

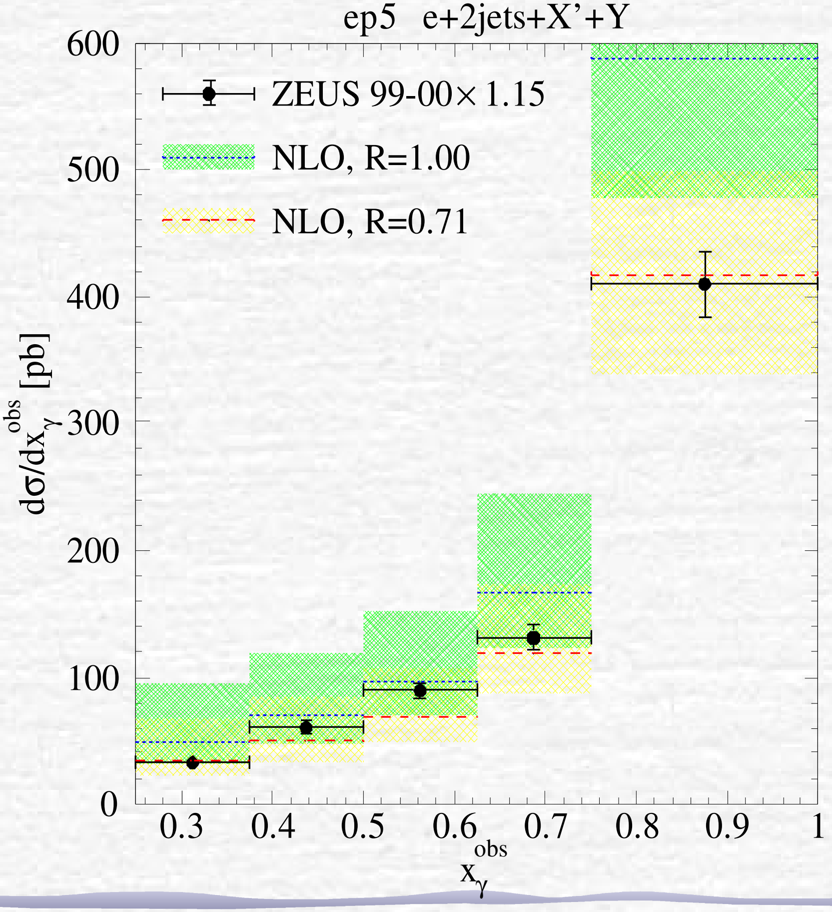


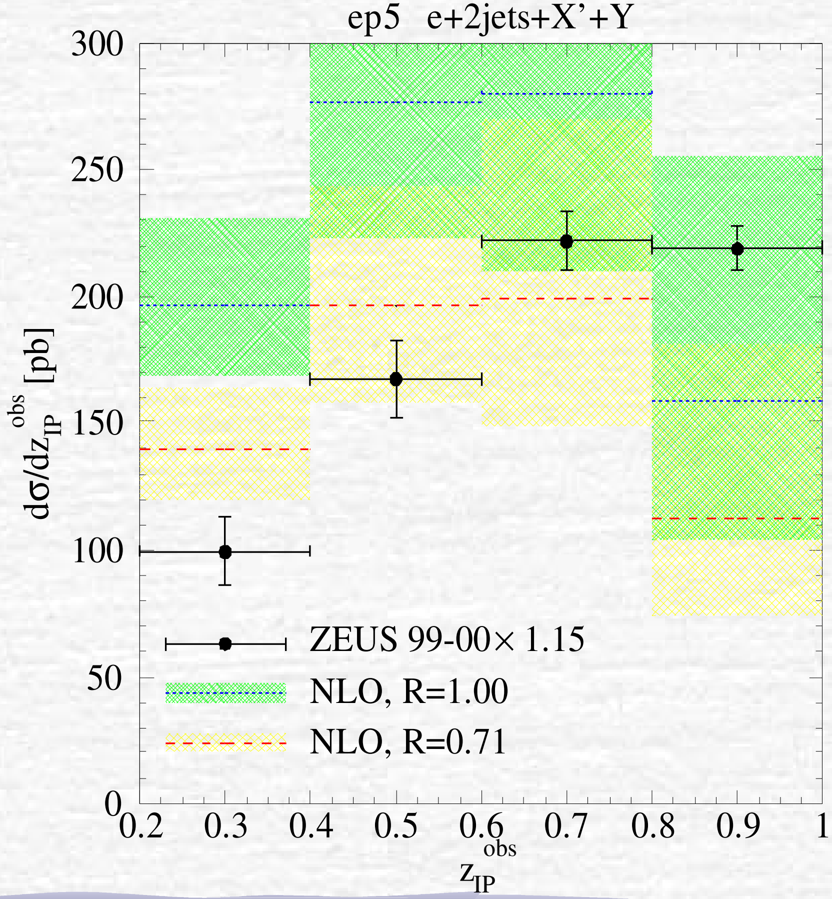
- x||P-depend.:Pomeron fl.



Factorization Breaking at NLO, ZEUS

- xgam-depend.:dir./resol.
- z||P-depend.:gluon in po.





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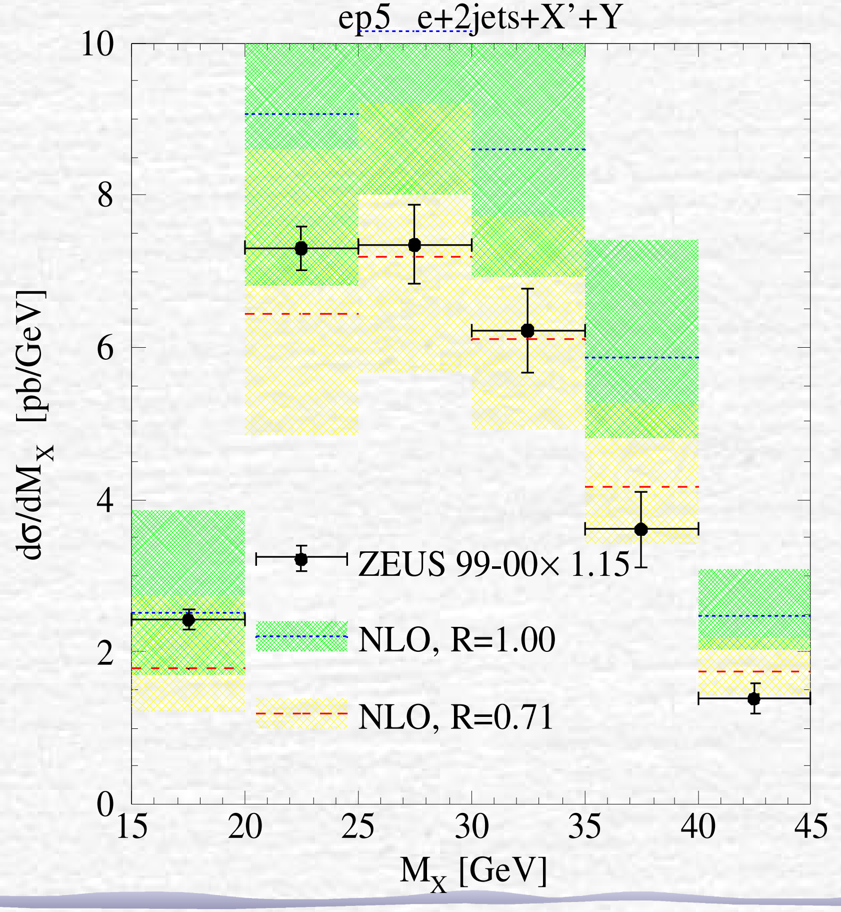
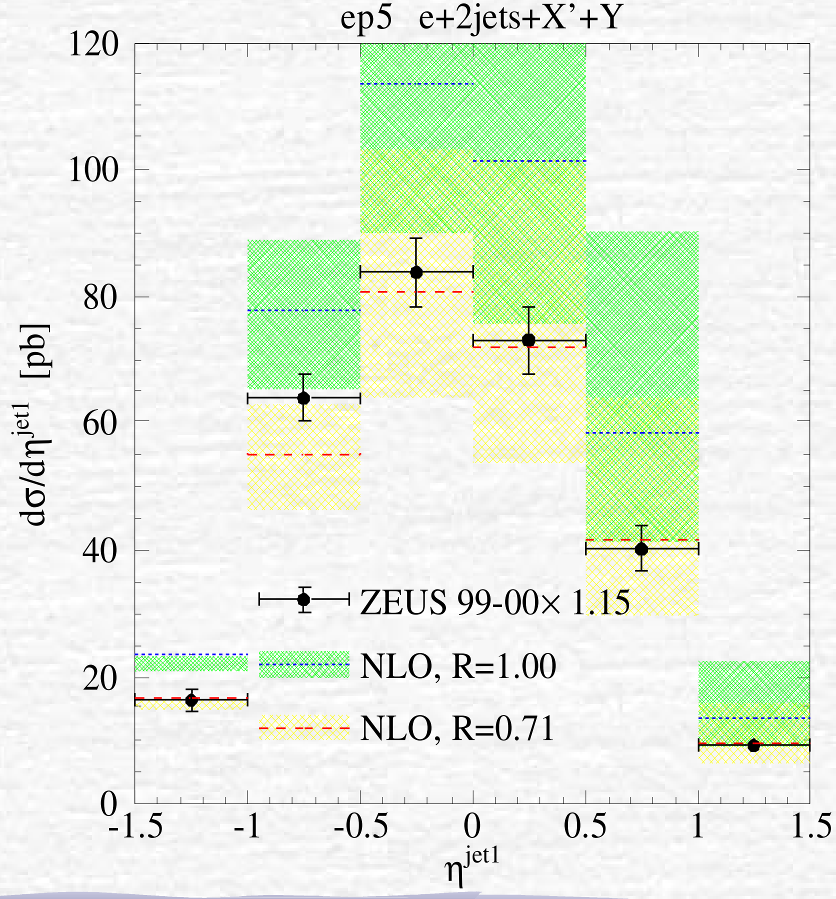
Factorization Breaking at NLO, ZEUS

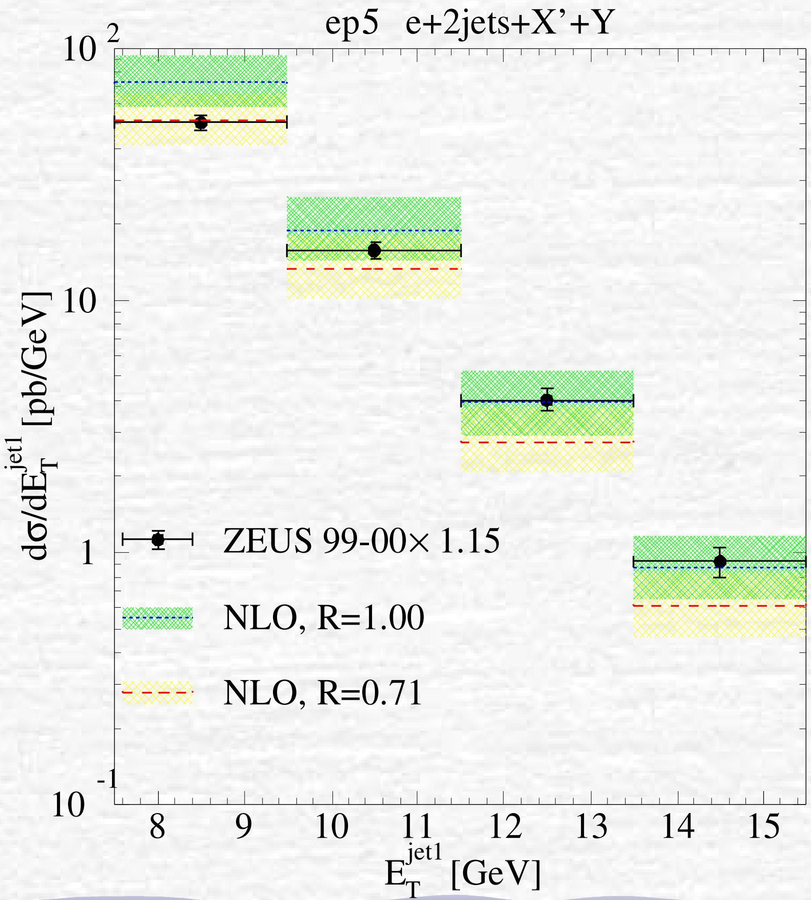
- MX-dependence
- eta^{jet1}-dependence





Factorization Breaking at NLO, ZEUS

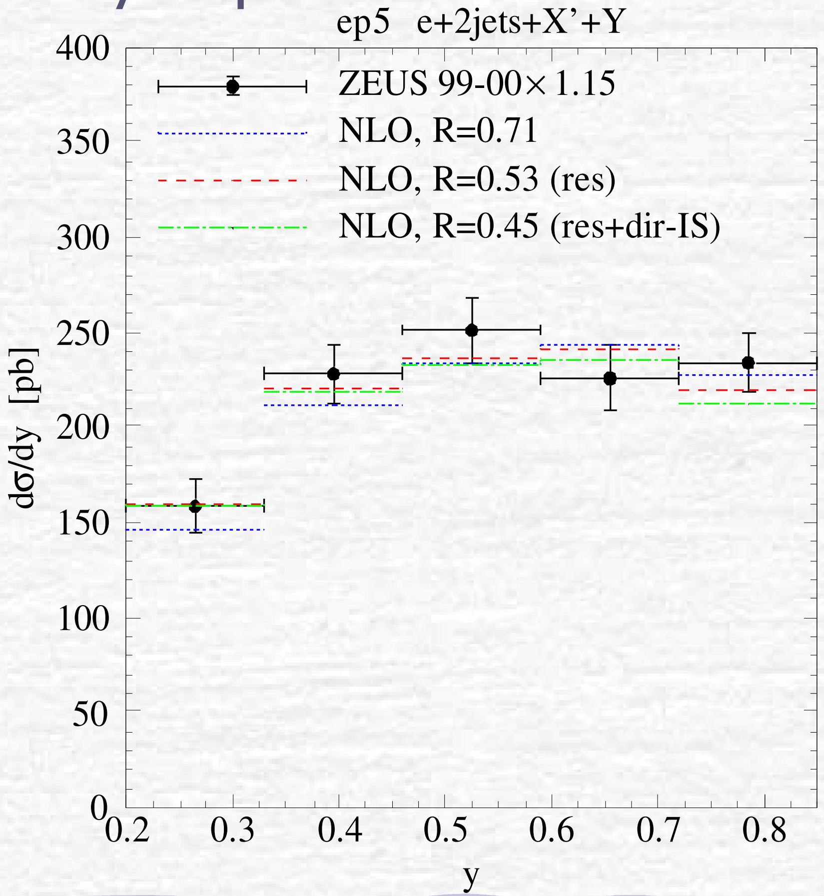
- ET^{jet1}-dependence
-

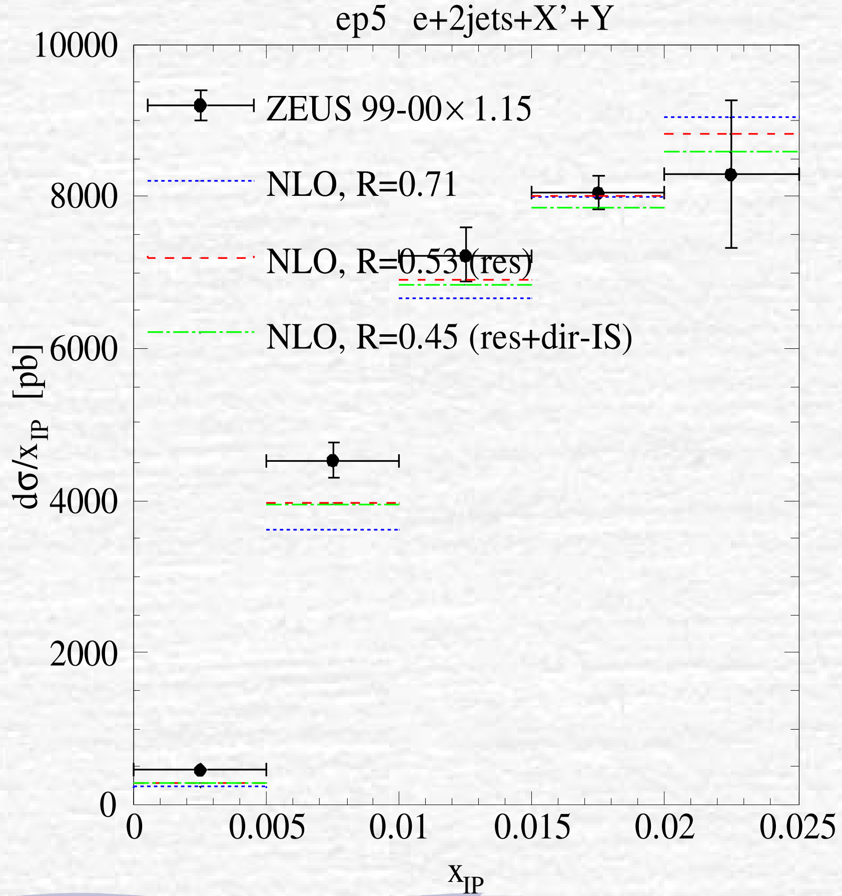


- Two highest ET-bins
- better described with
- R=1

Breaking in resolved or resolved/direct-IS

- y-depend.:Photon flux
- x||P-depend.:Pomeron fl.





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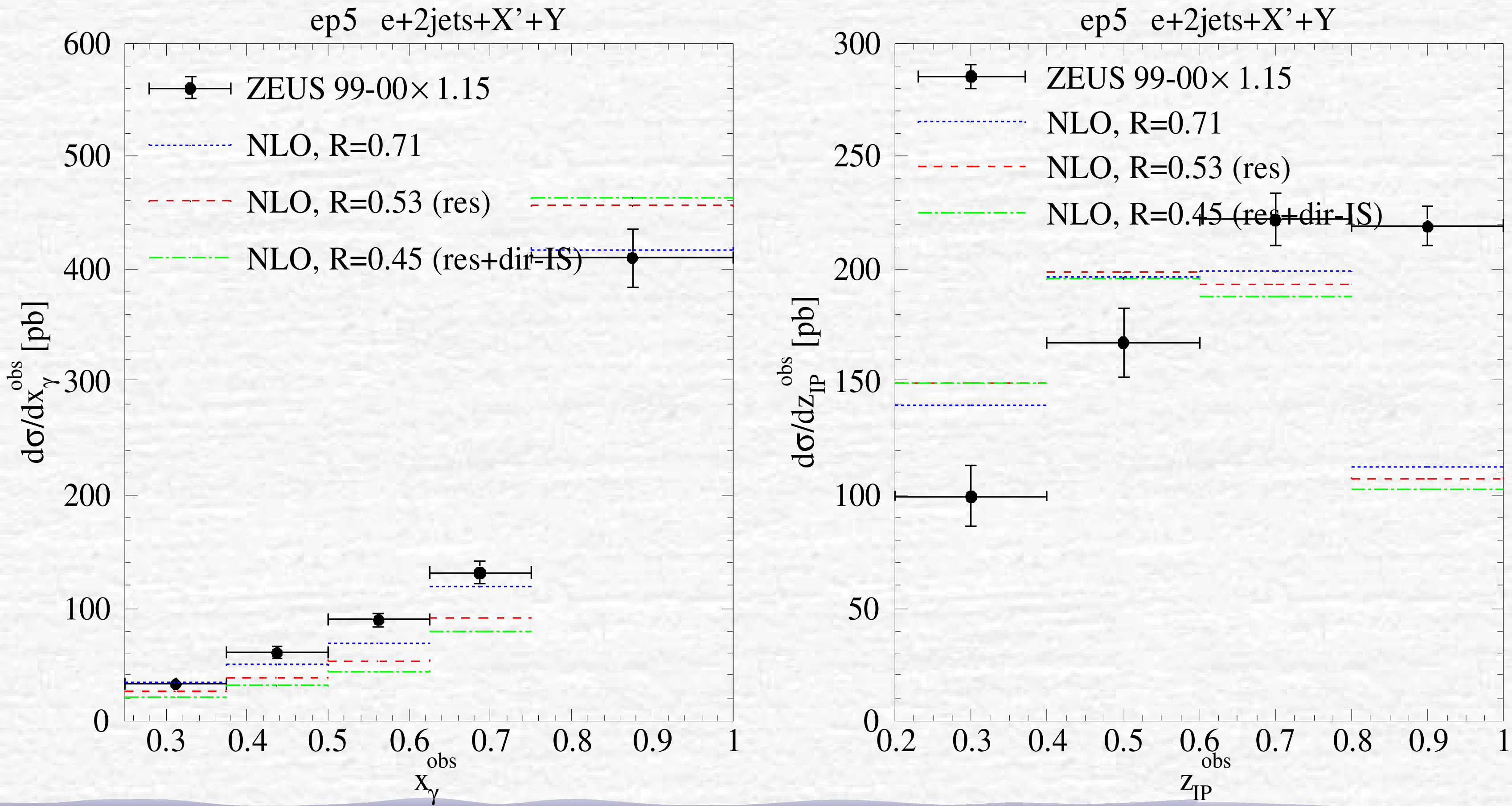
Breaking in resolved or resolved/direct-IS

- xgam-depend.:direct/res.
- z||P-depend.:gluon in po.



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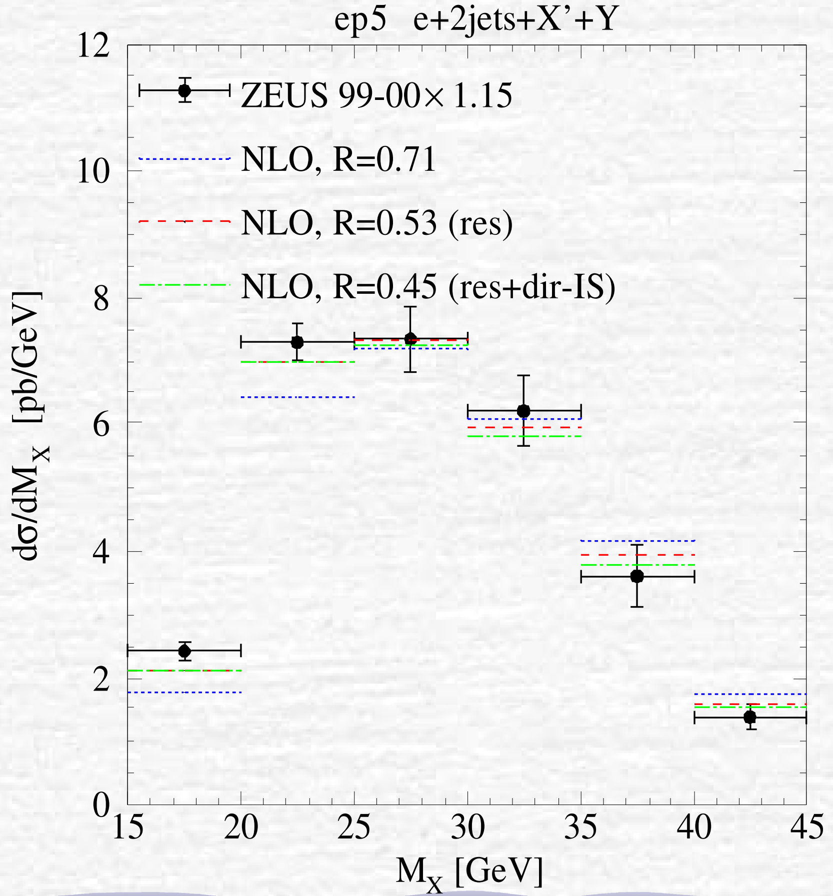
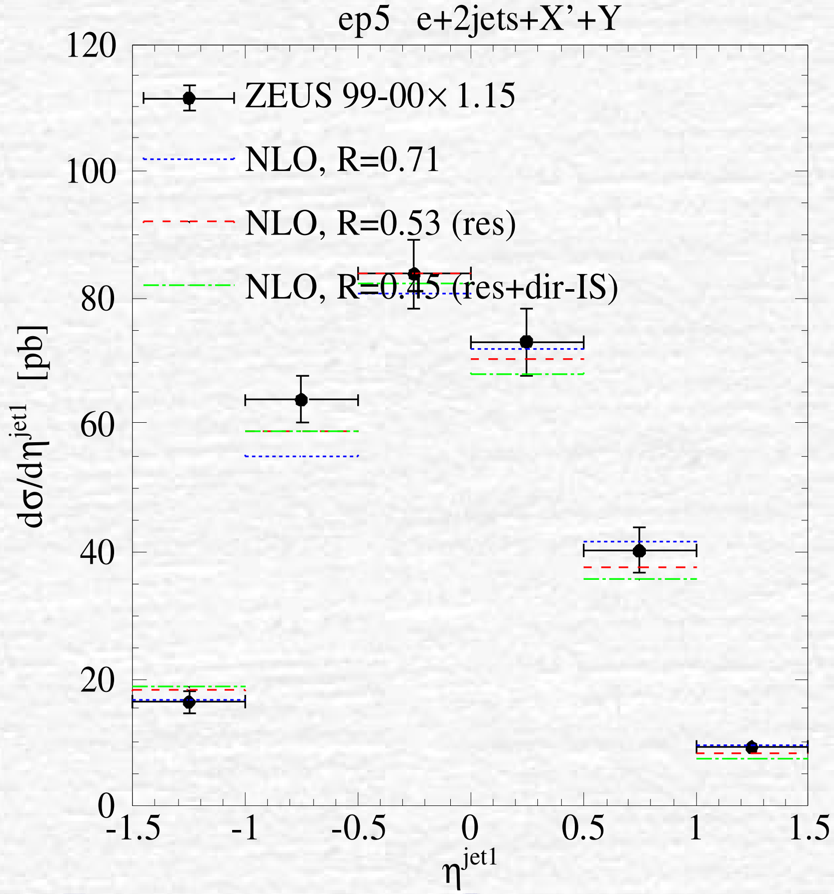
Breaking in resolved or resolved/direct_IS

- MX-dependence
- eta^{et1}-dependence





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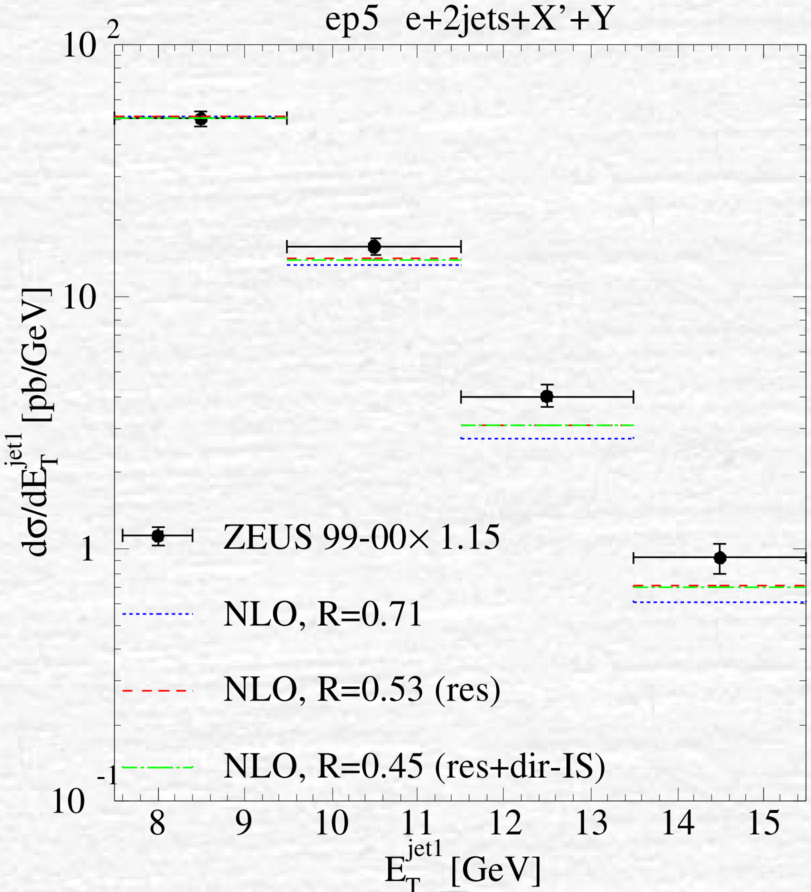
Breaking in resolved or resolved/direct-IS

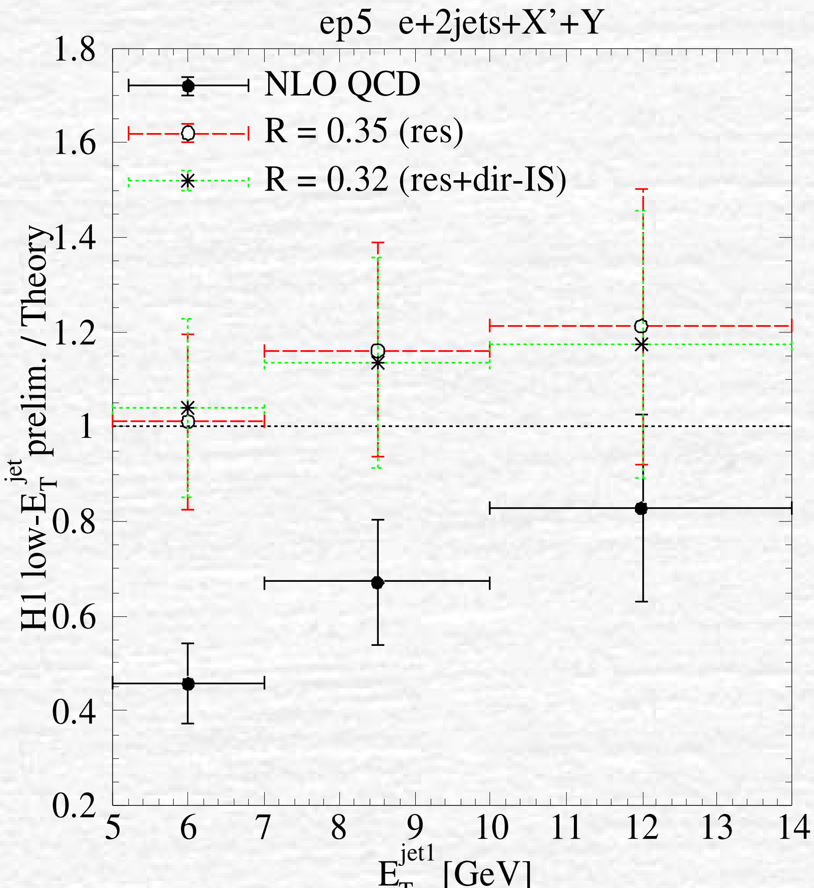
- ET_dependence



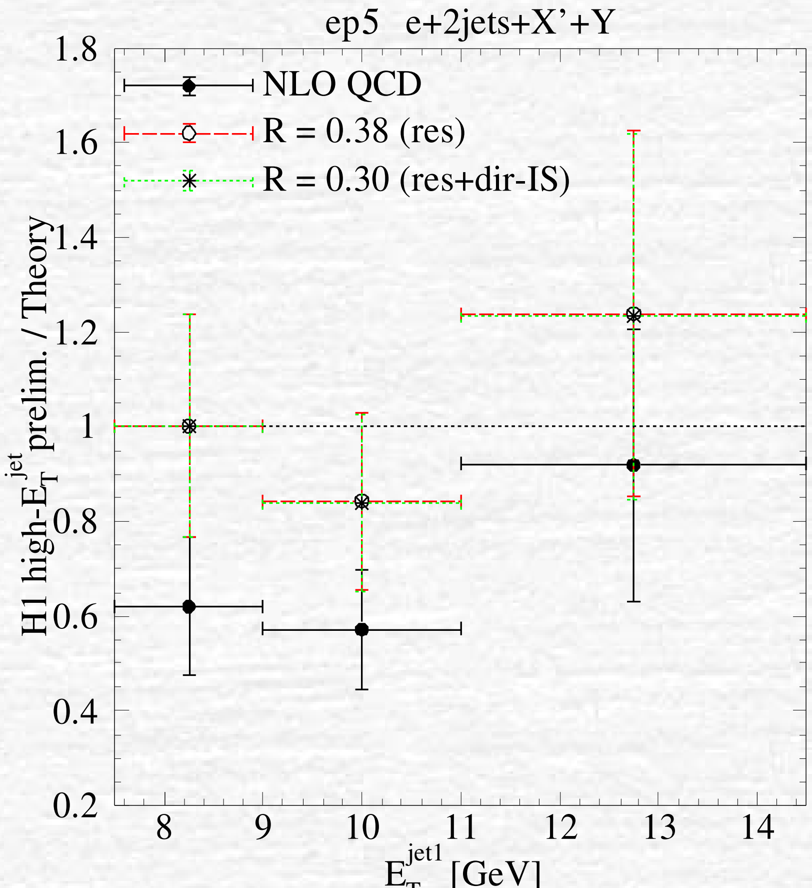
- Resolved or resolved/direct-IS
- slightly better
- than global suppression
- R=0.71 global supp.
- R=0.53 resolved supp.
- R=0.45 resolved/direct-IS suppression

Ratio data/theory, low-E_T and high E_T

- E_T depend. H1 low_E_T

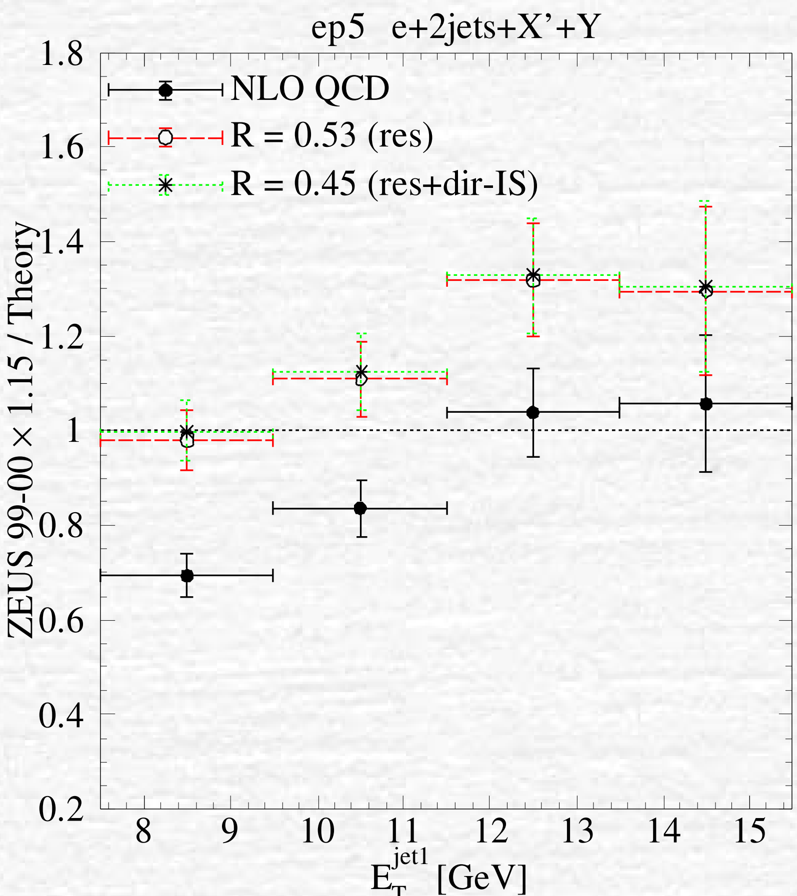


- E_T depend. H1 high E_T

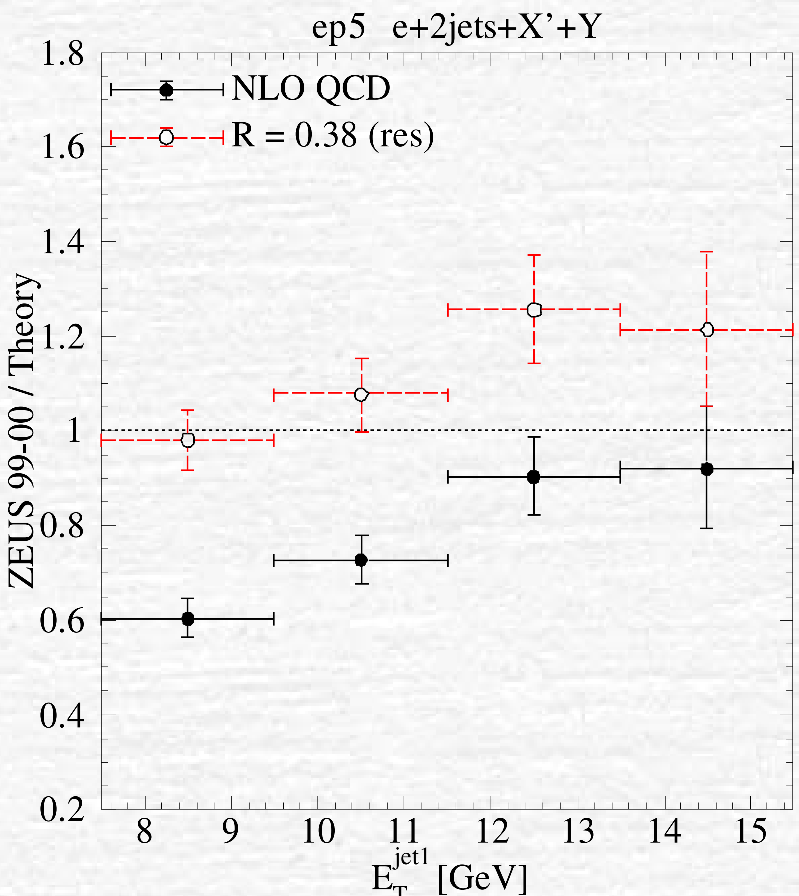


Ratio data/theory :ZEUS different norm

- E_T-depend norm paper



- Norm reduced by 15%



Conclusions

Hard diffraction: Factorizable or not?

- Deep inelastic scattering: Yes $\rightarrow$ Diffractive parton densities
- Hadronic scattering: No $\rightarrow$ Multipomeron exchanges
- Diffractive photoproduction of dijets: Yes global suppression of order 0.5 definitely established, suppression E_T dependent Initial state singularity at NLO
- Reolved suppression only or resolved/direct-IS suppression
- describes data almost equally well , suppression factor~1/3,
- little E_T dependence
- Agrees with two-channel eikonal model of Kaidalov et al.:
- Generalized vector meson dominance: $\gamma \rightarrow \rho, \omega, \ldots$
- Rapidity gap survival probability: R = 0.34