Forward jet production in DIS

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on behalf of the ZEUS collaboration

DIS 2007 Munich

Parton dynamics at low x

QCD Calculations

MC Models

Forward Jets

Forward Jet + Dijet

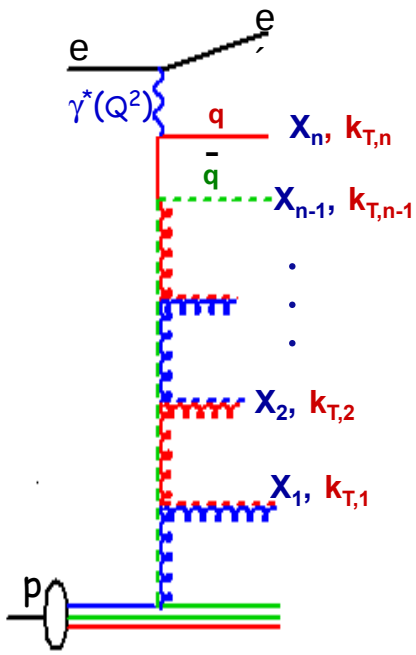
Summary & conclusions

Parton dynamics at low x

Perturbative expansion of parton evolution equations $\sim \Sigma_{mn} A_{mn} \ln(Q^2)^m \ln(1/x)^n$

⇨ **Cannot be explicitly calculated to all orders**

Approximations ⇨ summing subsets of terms



- **DGLAP:** $\sum (\alpha_s \ln Q^2)^n$

  Ordering in x, *strong ordering in* k_T

  $x_1 > x_2 > \ldots > x_{n-1} > x_n = x_{Bj}$

  $k_{T,1}^2 << k_{T,2}^2 << \ldots k_{T,n-1}^2 << k_{T,n}^2 \approx Q^2$

- **BFKL** : $\sum (\alpha_s \ln (1/x))^n$

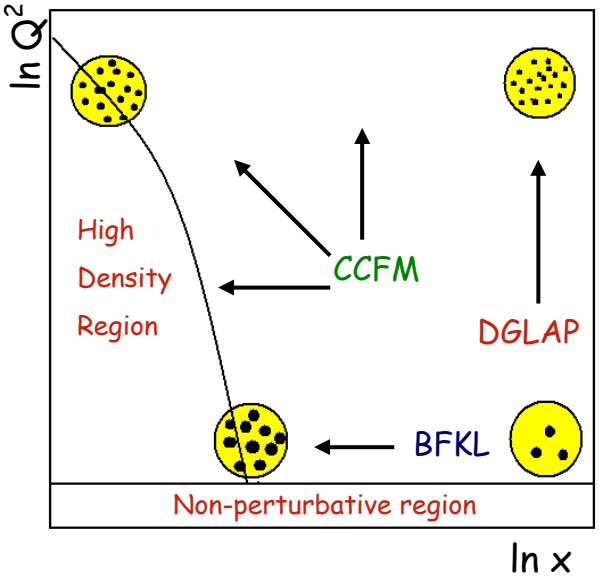
  Strong ordering in x, *no* k_T *ordering*

  $x_1 >> x_2 >> \ldots >> x_{n-1} >> x_n = x_{Bj}$

- **CCFM** : $\ln Q^2$ and $\ln (1/x)$

  Angular ordering

  $\theta_n >> \theta_{n-1} >> \ldots >> \theta_2 >> \theta_1$

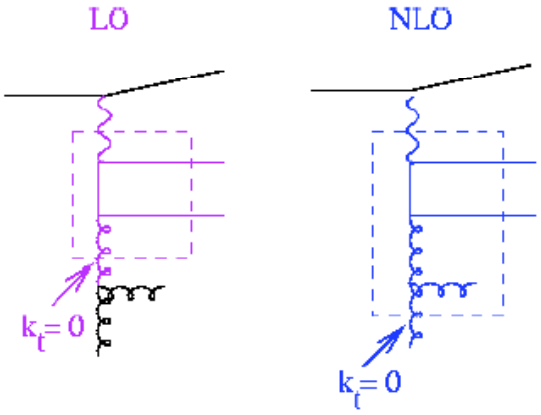


- **DGLAP successful at high Q^2 but expected to break down at low Q^2 and low x**
- **BFKL should be applicable at very low x**
- **CCFM expected to be valid in whole x, Q^2 range**

QCD Calculations

DISENT/NLOJET++: Fixed order QCD partonic cross section, on mass shell ME + DGLAP , (collinear factorization)

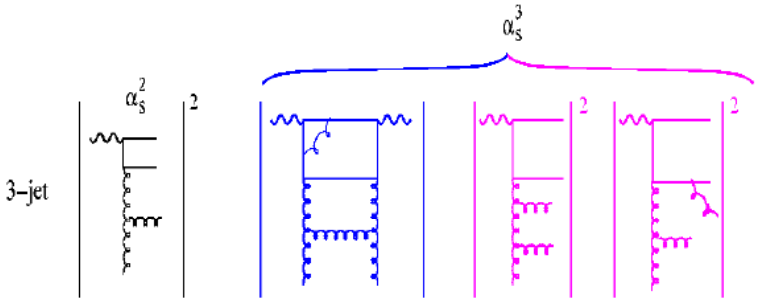
DISENT



+ Virtual Corr. to LO

- NLO for dijets: $O(\alpha_s^2)$

NLOJET++

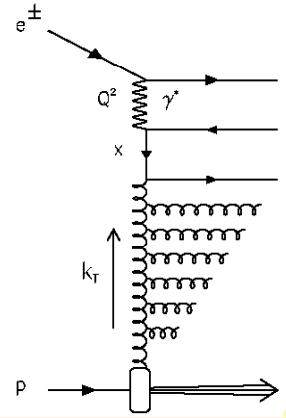


- NLO for 3-jets: $O(\alpha_s^3)$

MC Models

LEPTO: LO ME on mass shell + PS in DGLAP

→ ***Strong ordering in k_T***



CASCADE: LO off mass shell ME + PS based on k_T factorized **CCFM** evolution

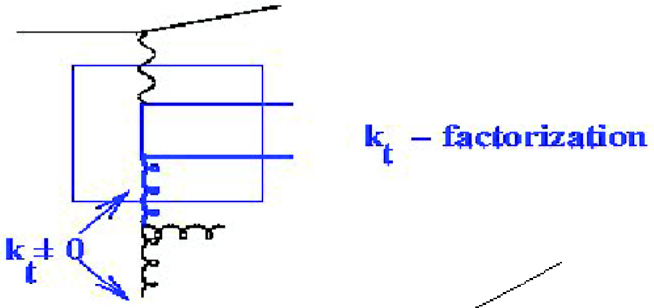
transverse momentum of emitted gluon $k_\perp > k_\perp^{cut}$

uPDF set1 : $k_\perp^{cut} = 1.33$ GeV

uPDF set2 : $k_\perp^{cut} = 1.18$ GeV

Non-singular term in splitting function

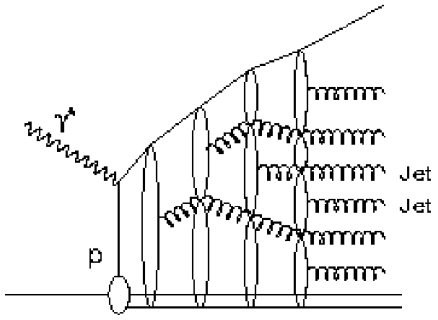
At small x_{Bj} ***no ordering in k_T***



ARIADNE: implementation of Color Dipole Model (CDM)

→ **Independently radiating dipoles formed by emitted gluons**

→ ***Random walk in k_T***



Two versions, with defalt tuning (default) and retuned by H1 (tuned)

Forward Jets

Event & Jet selection

Kinematic range

98-00 Data, $L \cong 82\ pb^{-1}$

$20 < Q^2 < 100\ GeV^2$

$0.0004 < x_{Bj} < 0.005$

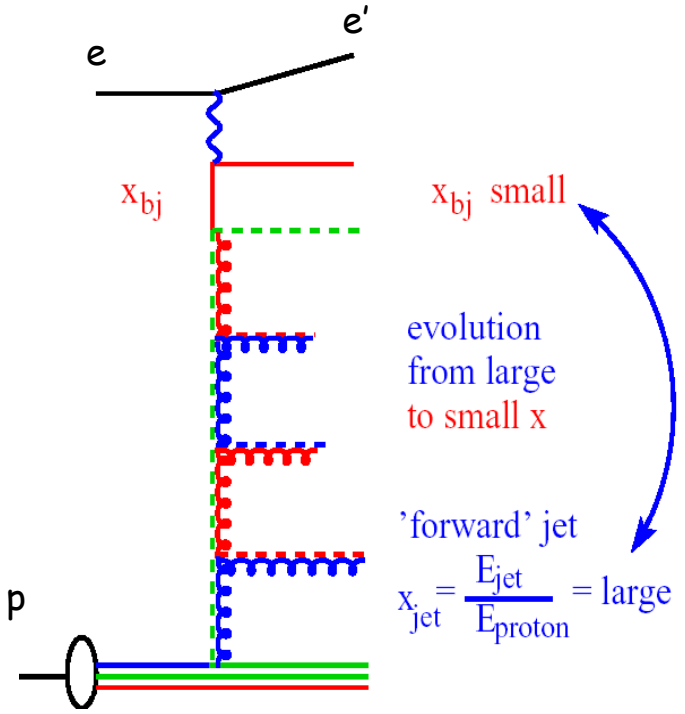
$0.04 < y < 0.7$

Forward Jet selection

Inclusive K_T algorithm

$E_t^{jet} > 5\ GeV$

$2 < \eta^{jet} < 4.3$

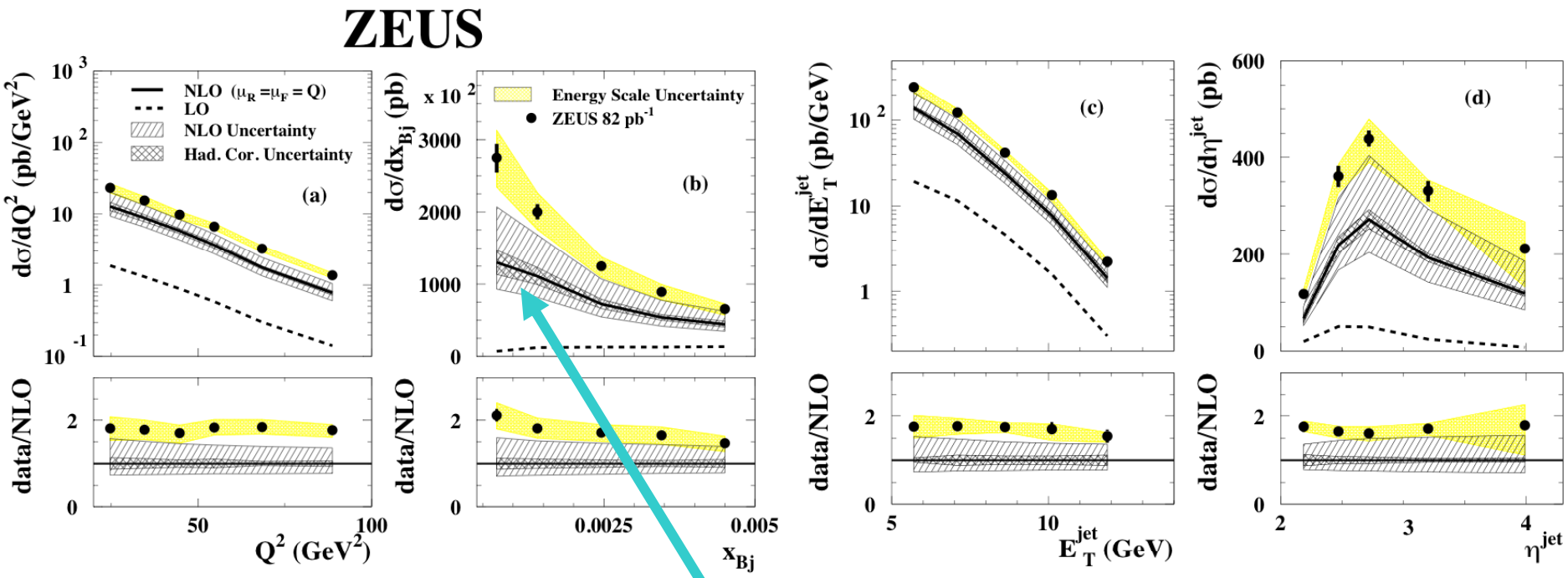


1.4 unit more forward than before

$0.5 < (E_t^{jet})^2/Q^2 < 2$ → $E_t^{jet} \sim Q^2$ suppresses DGLAP evolution

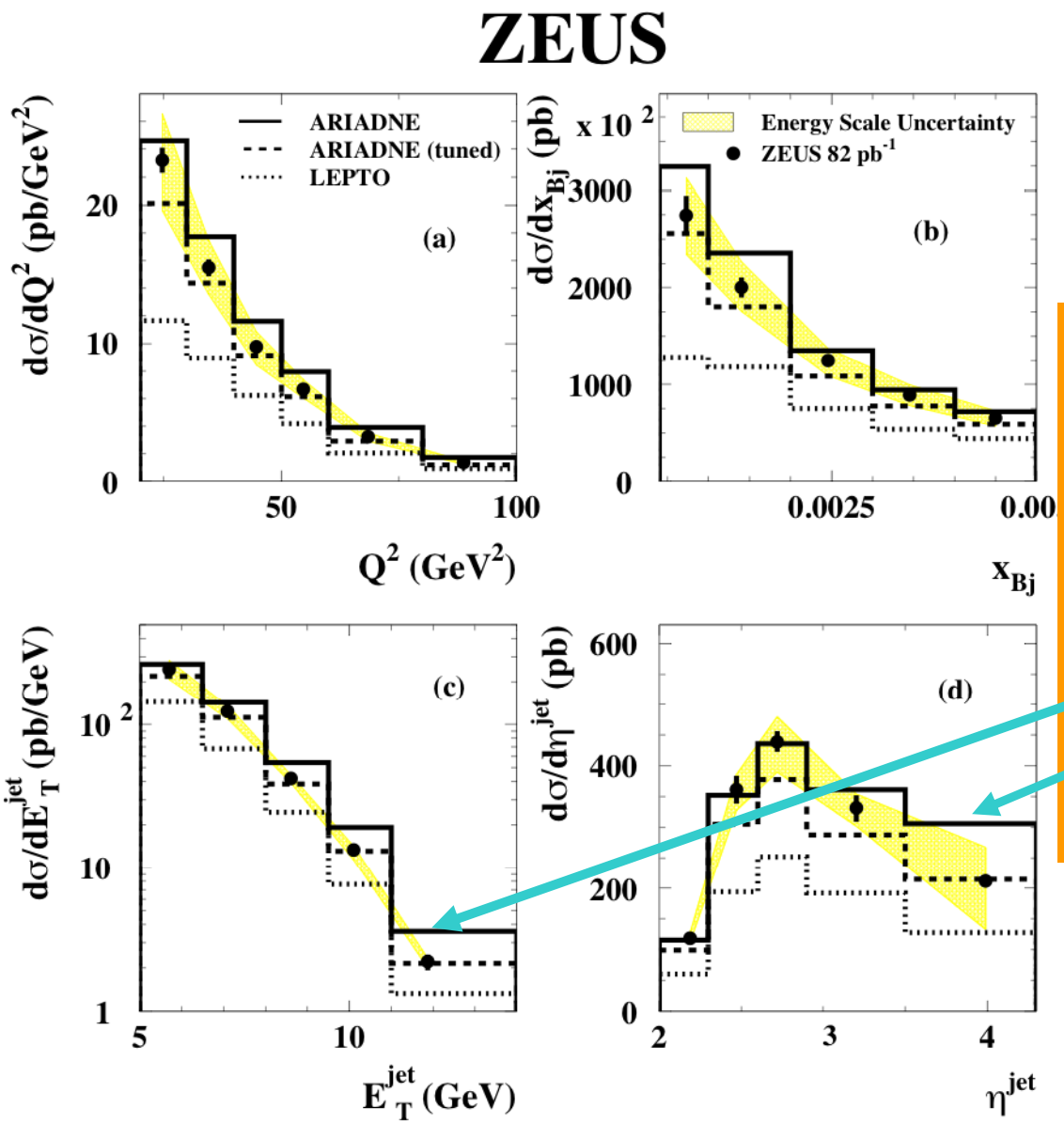
$x_{jet} > 0.036$ → $x_{jet} = E_{jet}/E_{proton} >> x_{Bj}$ enhances BFKL evolution

Forward Jets



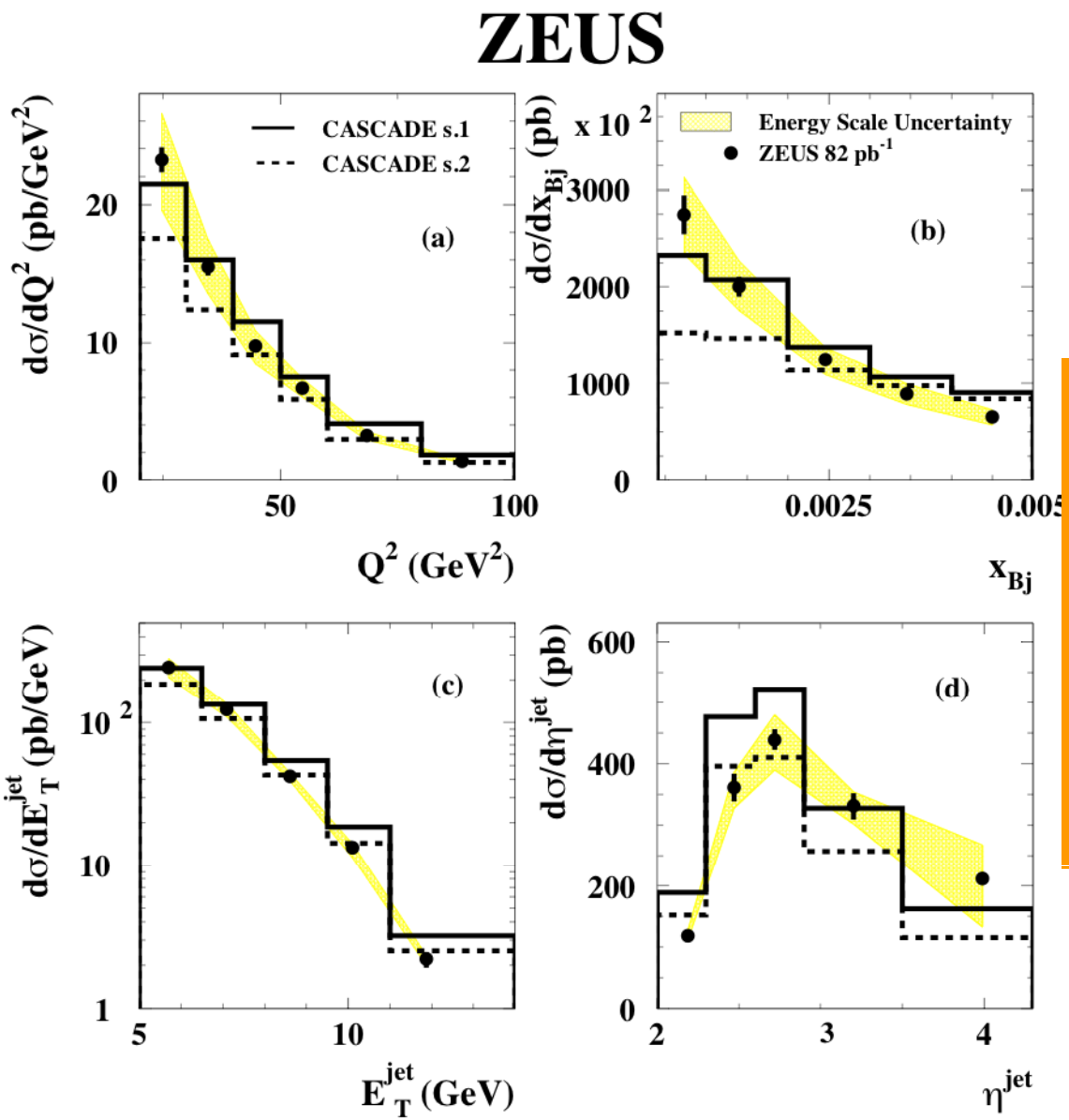
NLO below data, especially at small x_{Bj} but theoretical uncertainty is large

Forward Jets



- Lepto doesn't suffice
- Ariadne default underestimates high E_t^{jet}, overestimates high η^{jet} (proton remnant)
- Ariadne tuned is good

Forward Jets



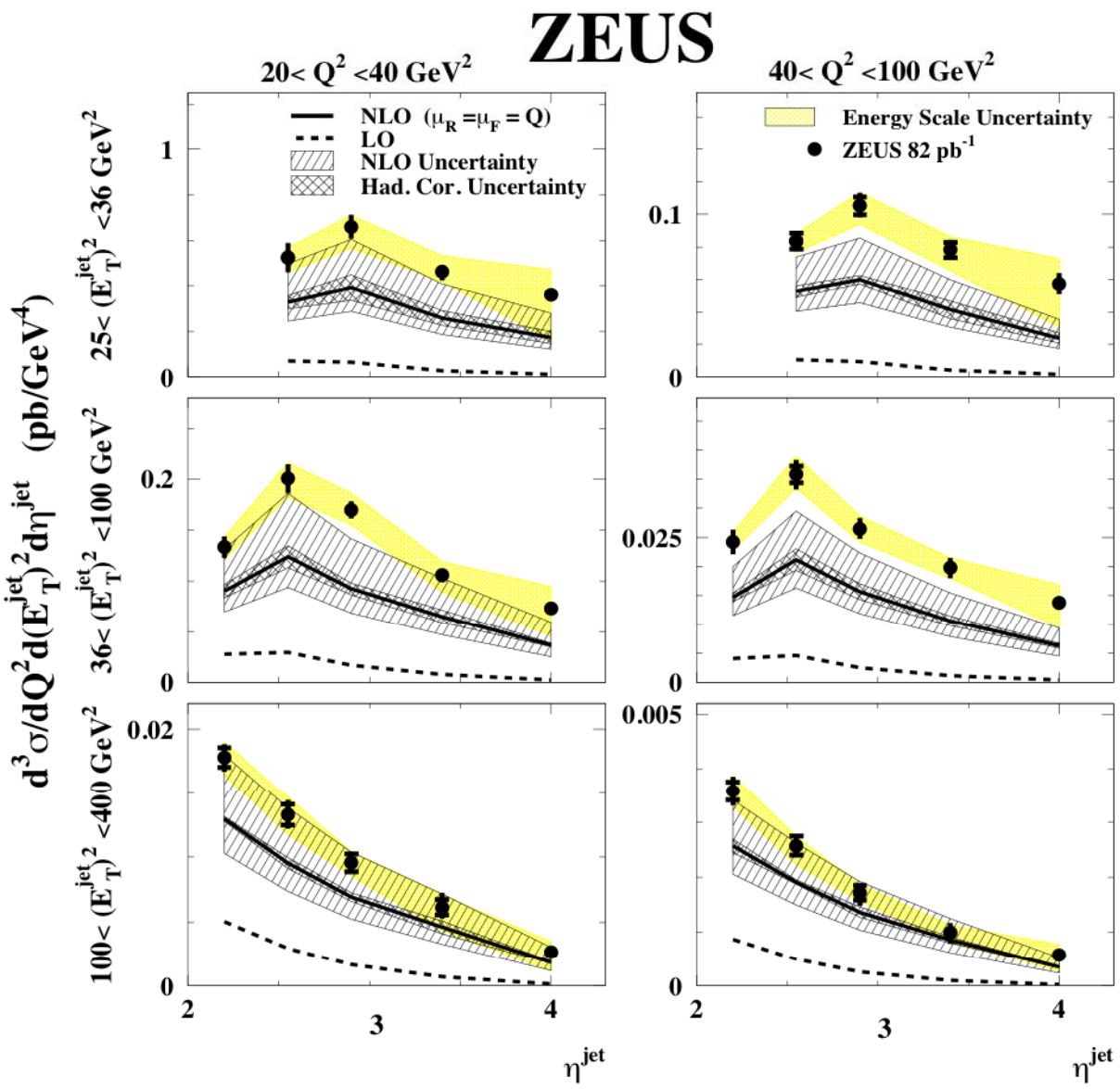
Non singular term (in set 2) reduces cross section, but not improves agreement

Shape of all distributions disagrees with data

Shape is a problem

Forward Jets

Triple differential cross sections

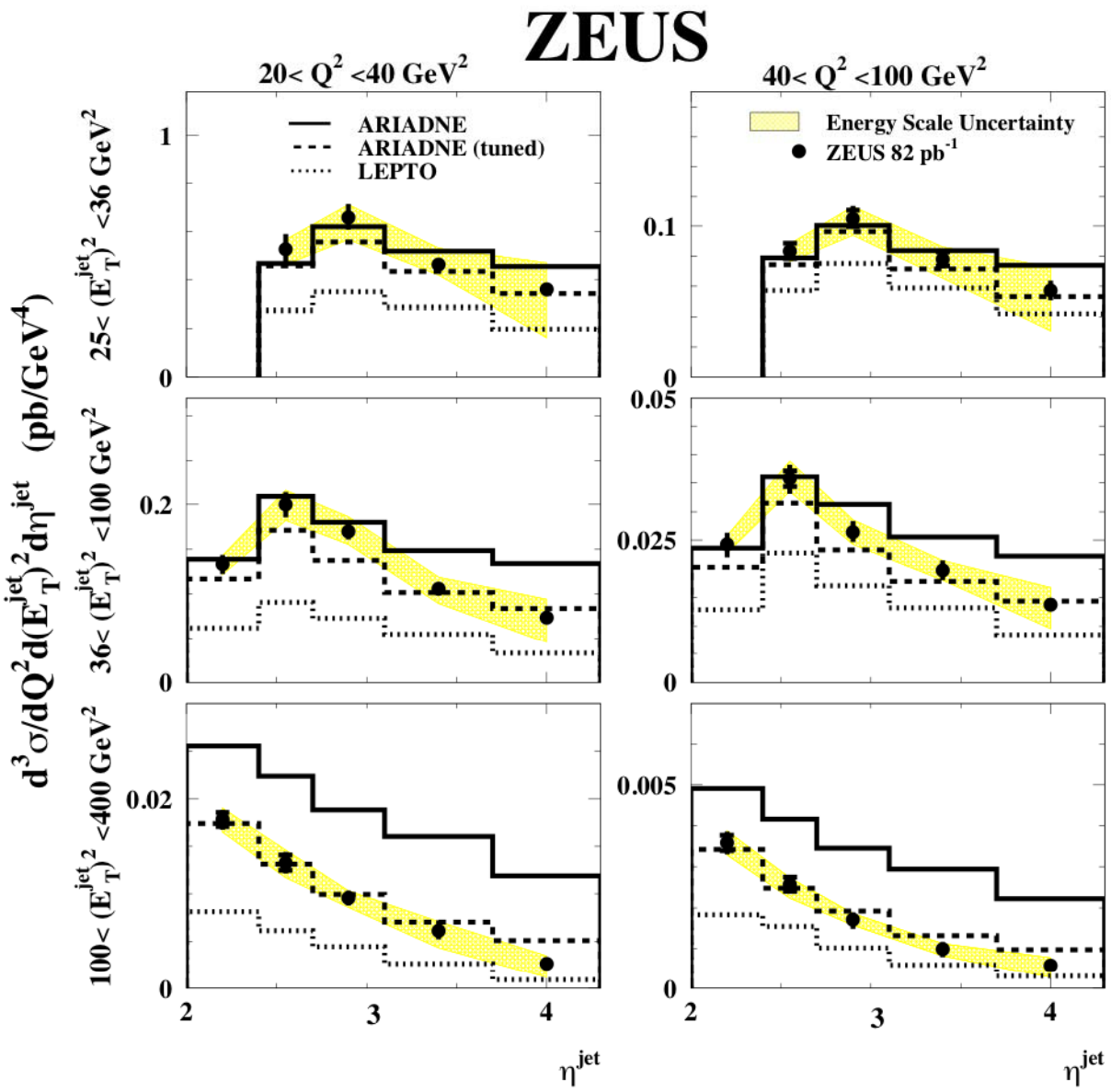


NLO is below data

Large theoretical uncertainty prevents decisive conclusion

Forward Jets

Triple differential cross sections



Pronounced excess of high E_t^{jet} in Ariadne default

Ariadne tuned is fine

Forward Jet + Dijet

Event & Jet selection

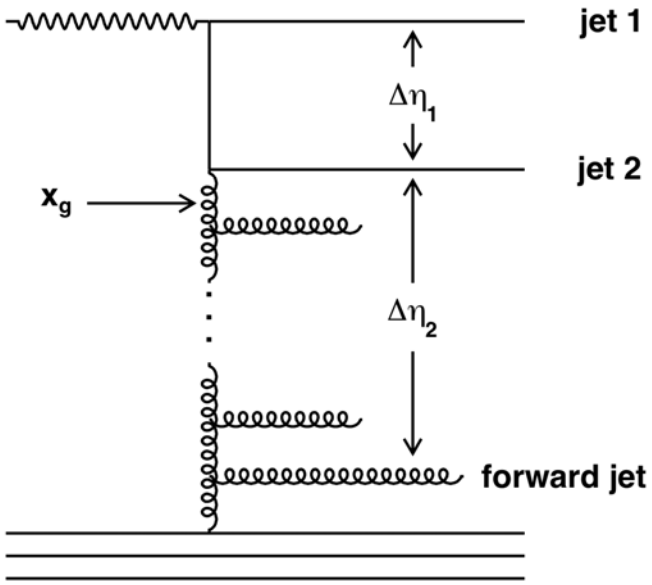
Kinematic **range the same as for inclusive forward jets**

Forward jet the same,

$0.5 < (E_t^{jet})^2/Q^2 < 2$ **constraint excluded**

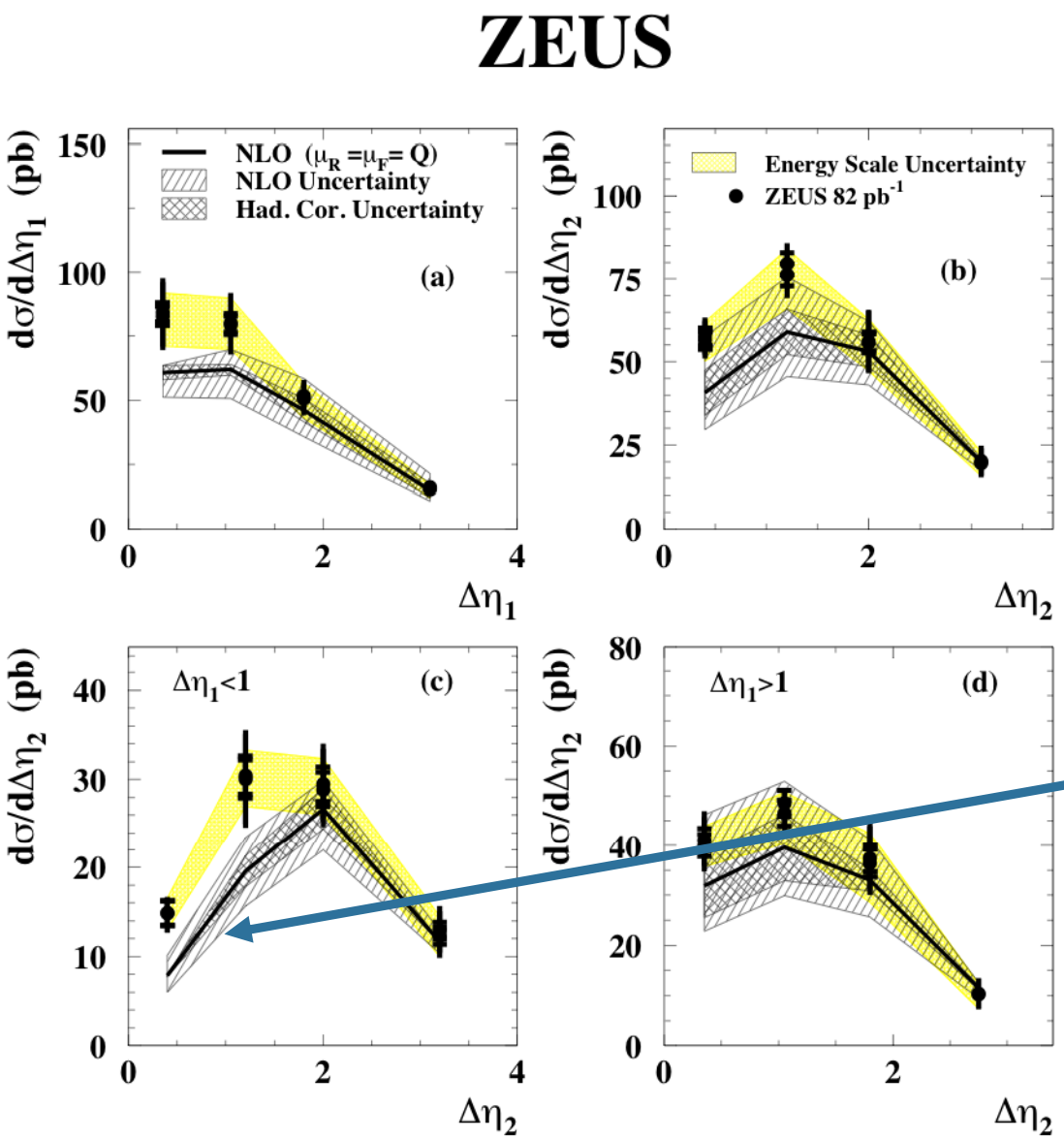
Two additional jets with $E_t^{jet} > 5$ **GeV**

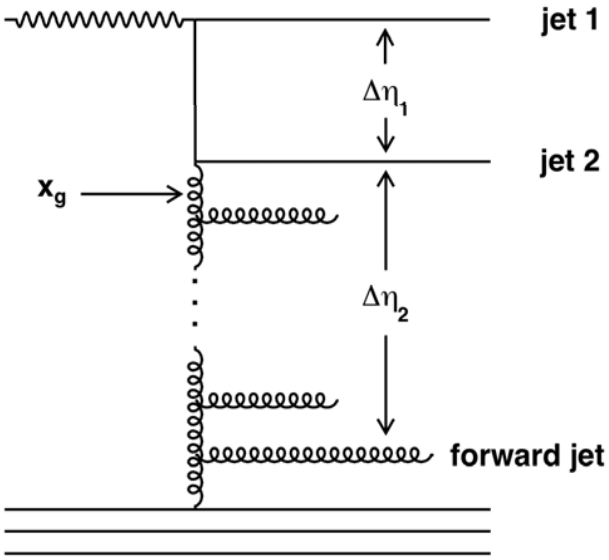
$\eta_{el} < \eta_{jet\ 1} < \eta_{jet\text{-}2} < \eta_{forward\text{-}jet}$



Forward Jet + Dijet

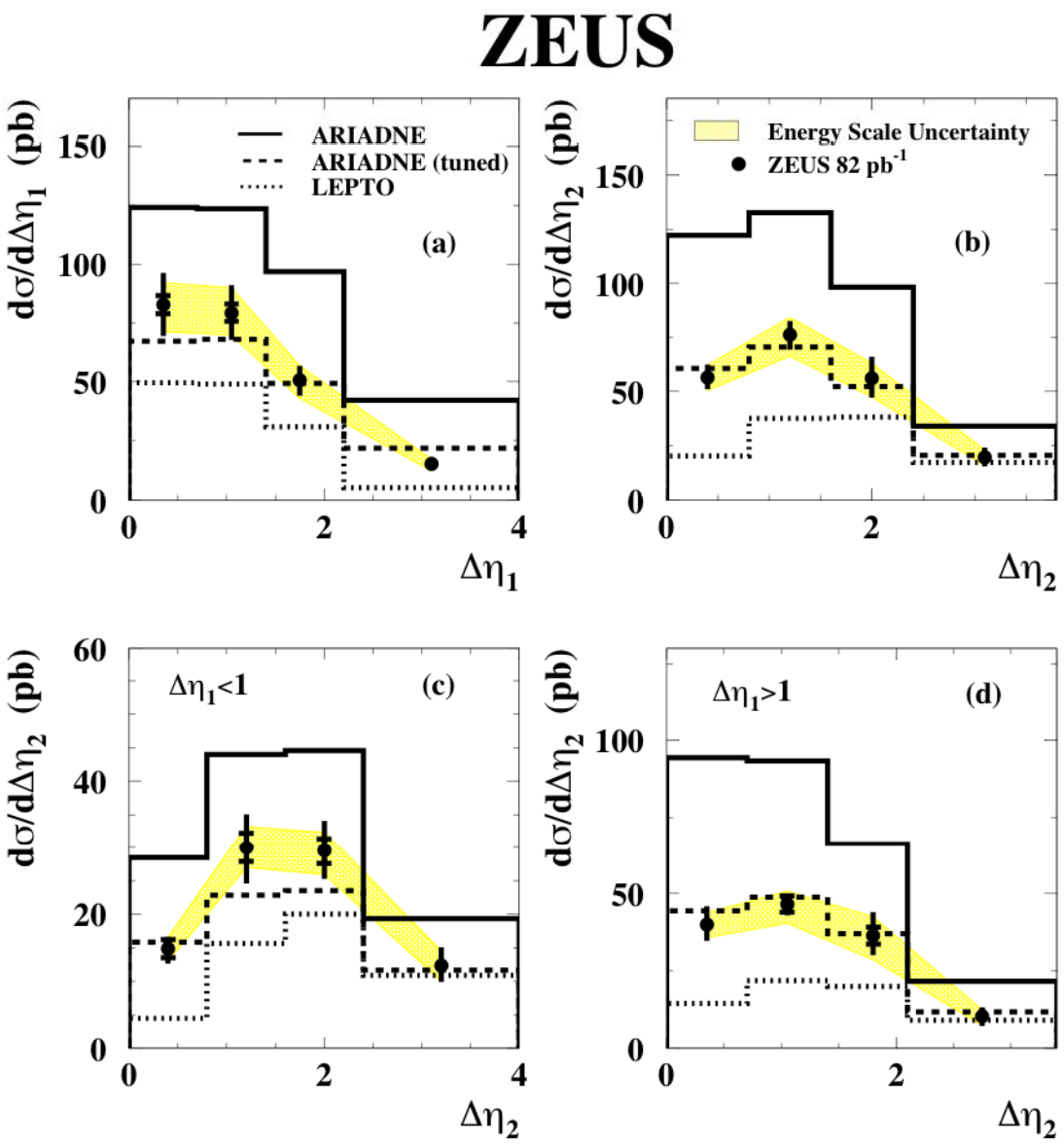
NLOJET++ vs data





Small $\Delta\eta_1$ and $\Delta\eta_2$ jets are most forward. At small x_{Bj} space is left for additional partons closer to the photon. NLOJET++ underpredicts many partons ➔ below data

Forward Jet + Dijet



Lepto below data

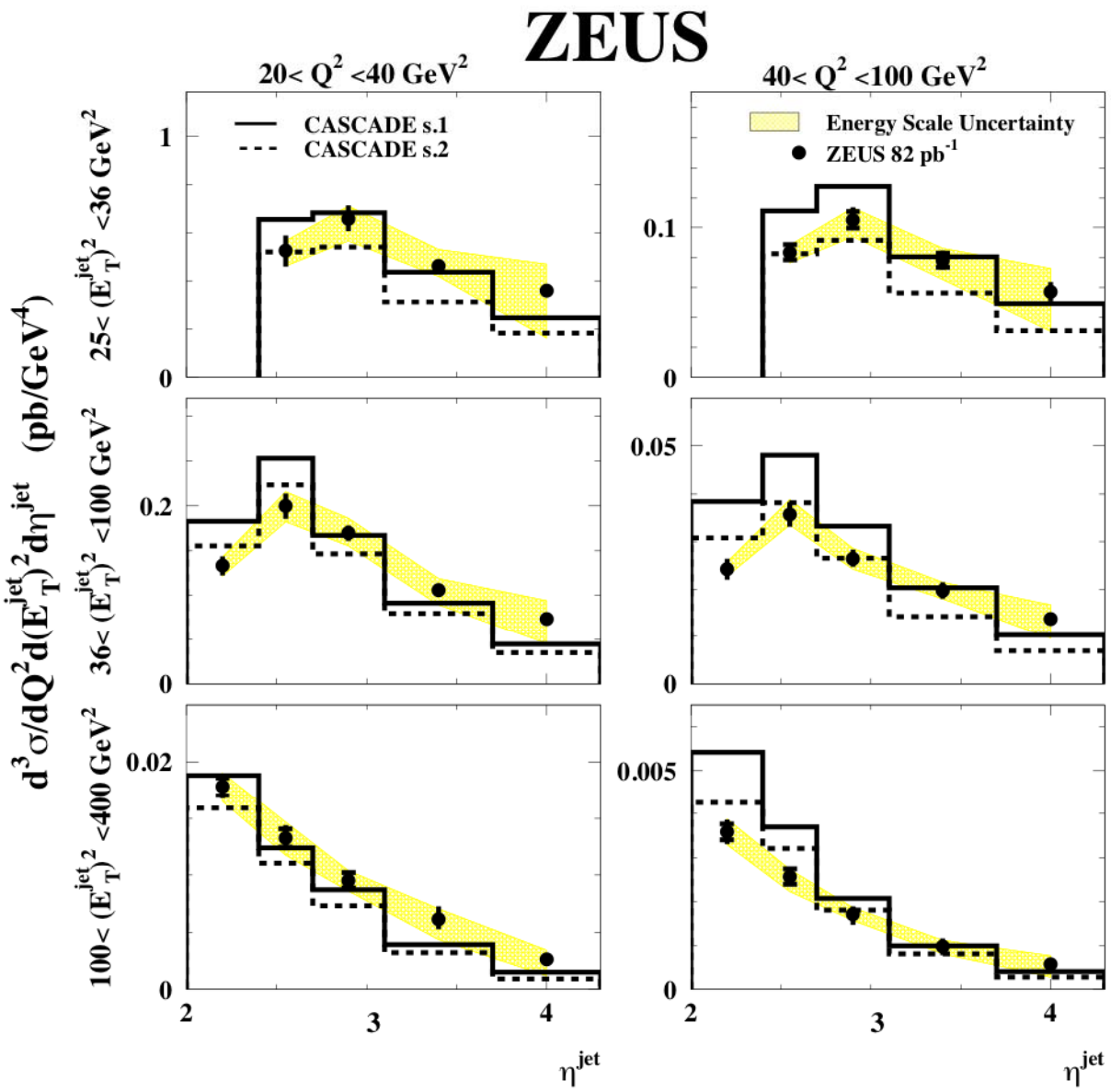
Ariadne default pronouncedly above data –> too high multigluon emission rate

Ariadne tuned is fine

Summary & Conclusions

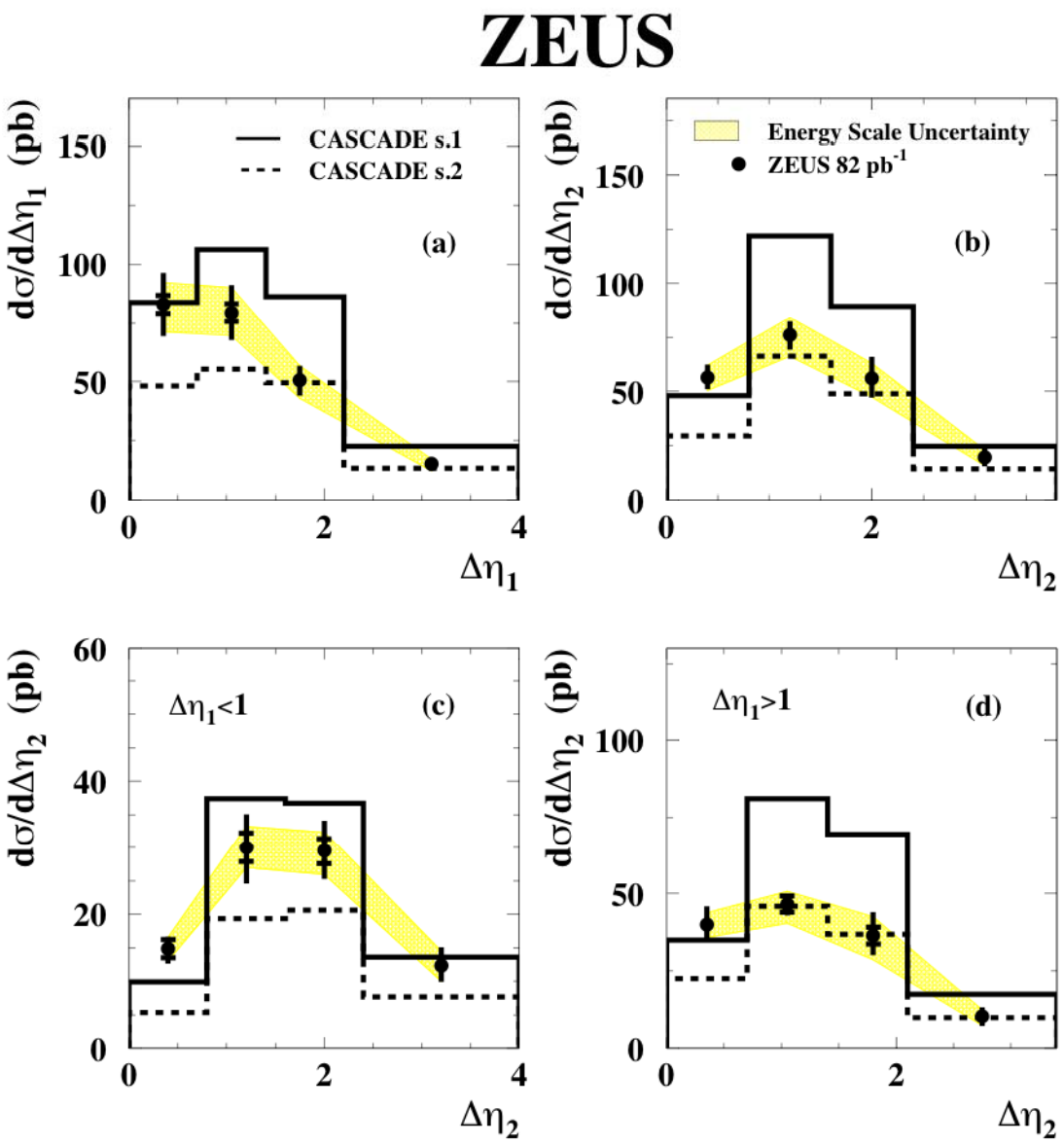
- ZEUS measured jets at small x_{Bj} in highly extended forward region
- NLO is significantly below the data for inclusive forward jets
- NLO for forward jet + dijet undershoots data in the region of pseudorapidities where multigluon emission is favoured
- LO DGLAP-based MC, Lepto, is twice below the data
- CDM (Ariadne) is capable of successfully describing the whole volume of the data
- Cascade MC fails to successfully describe the measurements, other sets of uPDF are to be tried. The data obtained could be highly useful for further uPDF adjusting

Forward Jets



Neither set accommodates for all data features

Forward Jet + Dijet



- Set 1 is above data
- Set 2 is below data

- ✓Hkjhlkhj
- ✓gkhgkjgh