Studies of the hadronic final state with the H1 detector

Daniel Traynor, QMUL

Recent Results from H1

- Photoproduction of Dijets with High Transverse Momenta at HERA.
- Multi-jet production in high Q2 neutral current deeply inelastic scattering at HERA and determination of α_s
- H1 Search for a Narrow Baryonic Resonance Decaying to K^0_s p($\bar{p}$)
- Measurements of Forward Jet Production at low x in DIS

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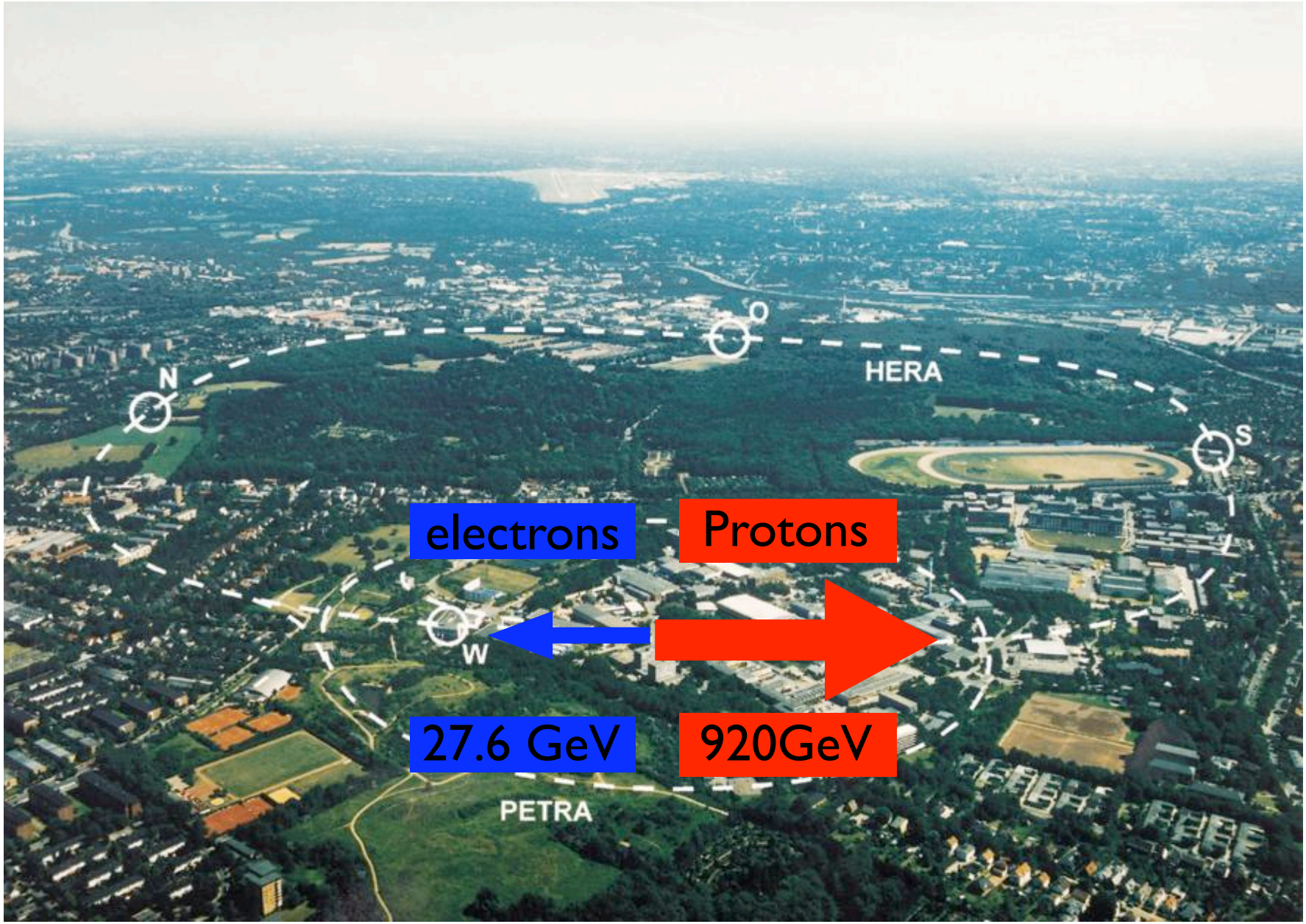
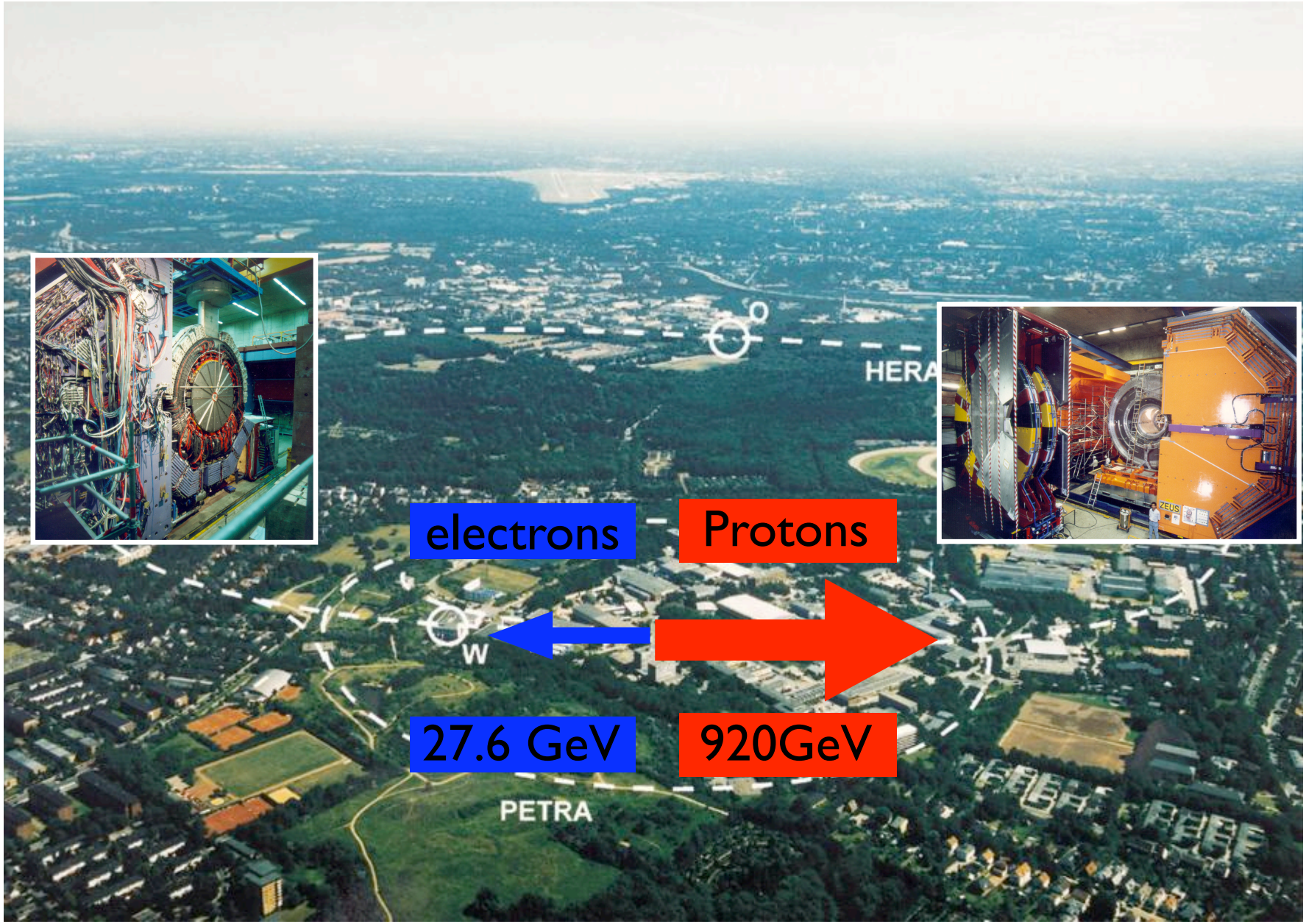
HERA + HI


O
HERA
N
S
W
PETRA


O
HERA
N
S
electrons
W
27.6 GeV
PETRA


HERA
N
O
S
W
electrons
Protons
27.6 GeV
920GeV
PETRA


HERA
electrons
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W
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electrons
Protons
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920GeV
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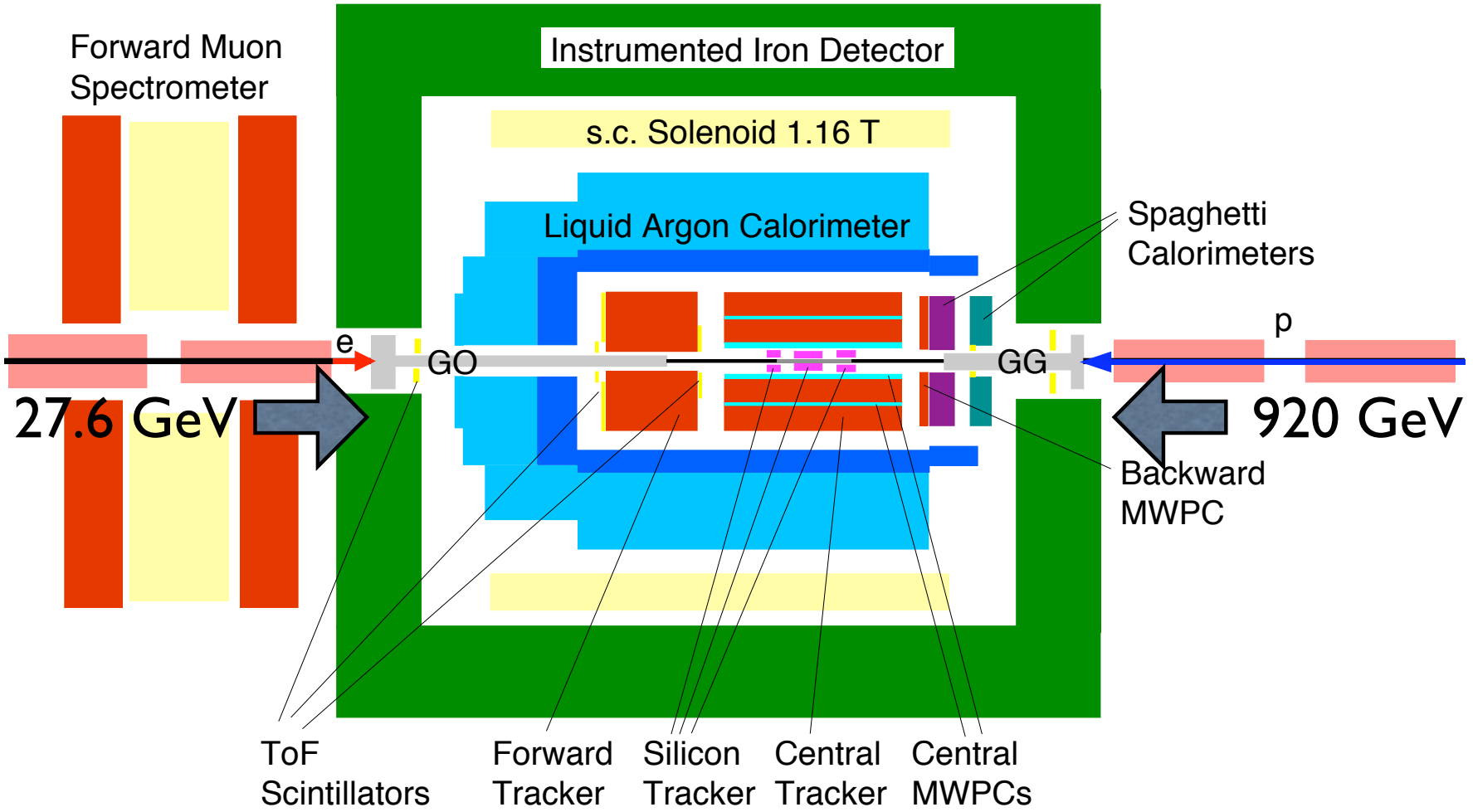
ZEUS

H1


Forward Muon
Spectrometer
Instrumented Iron Detector
s.c. Solenoid 1.16 T
Liquid Argon Calorimeter
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Calorimeters
e
GO
GG
p
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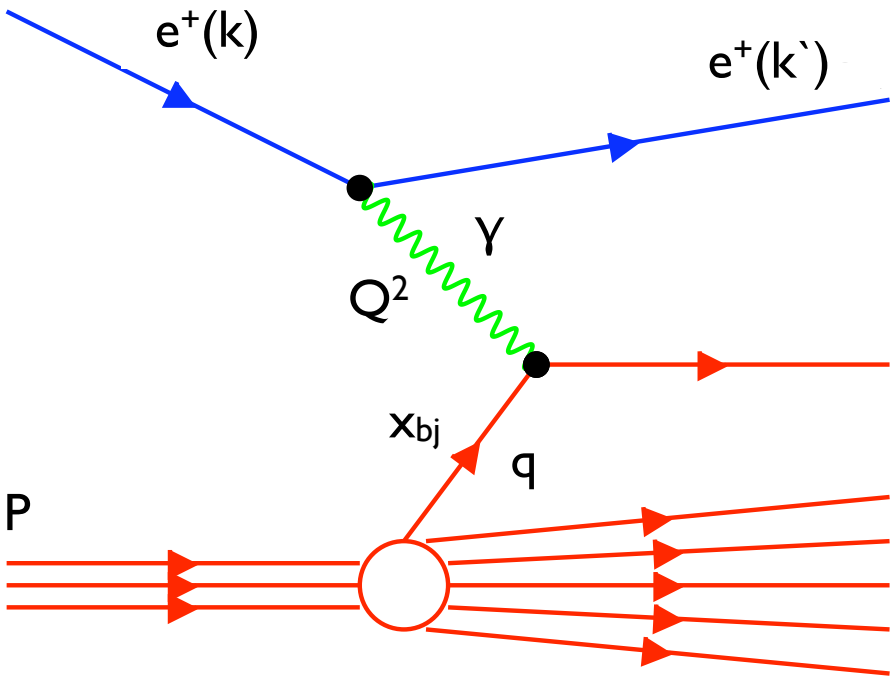
920 GeV
Backward
MWPC
ToF
Scintillators
Forward
Tracker
Silicon
Tracker
Central
Tracker
Central
MWPCs

Forward Jet Production at HERA



Kinematics

Four-momentum transfer squared

$Q^2 = -q^2 = (k-k`)^2$

Bjorken x (x_{bj})

$x = Q^2 / 2p.q$

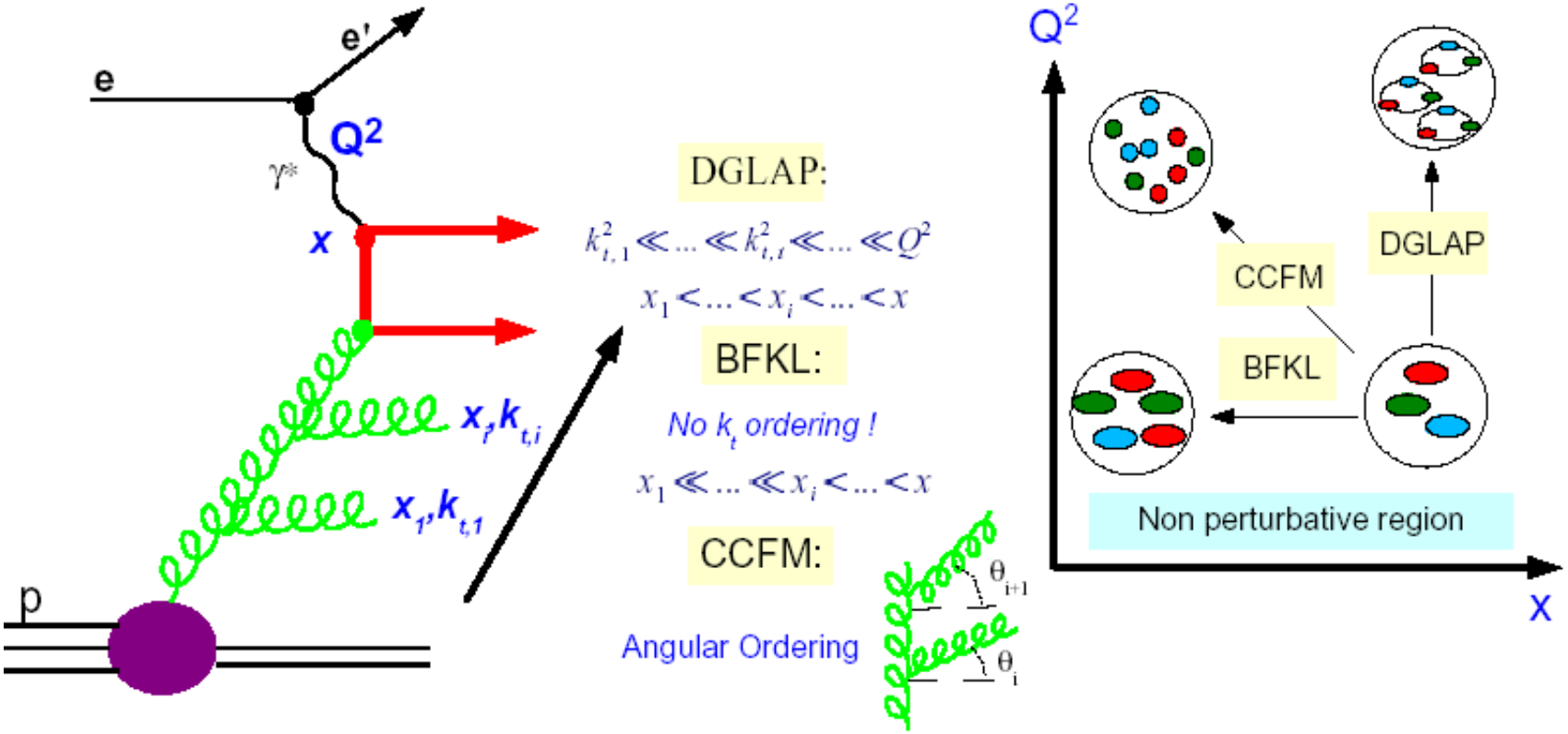
Inelasticity y

$y = p.q / p.k`$

$s = Q^2 / xy = 318$ GeV

Kinematics overstrained
calculable from electron or proton side

Parton Evolution



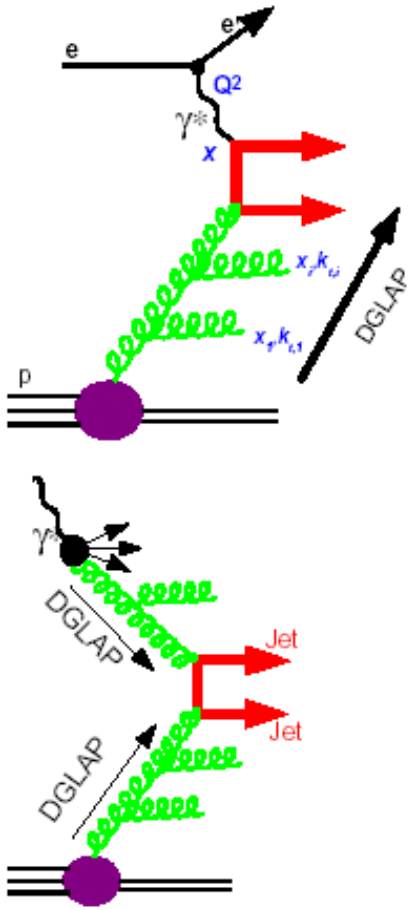
x_i = longitudinal momentum fraction

k_t = transverse momentum

Monte Carlo and NLO predictions

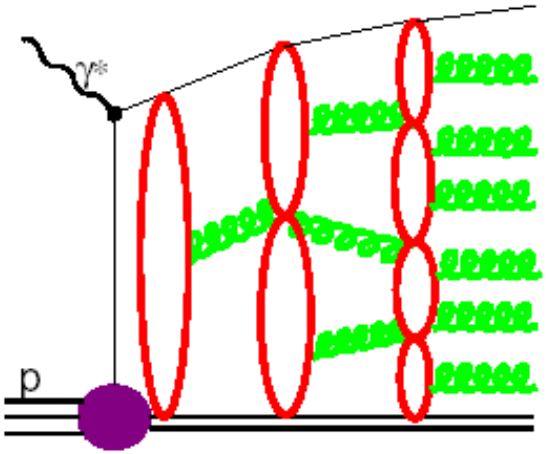
DGLAP Type

DISENT, RAPGAP



'BFKL'-Type

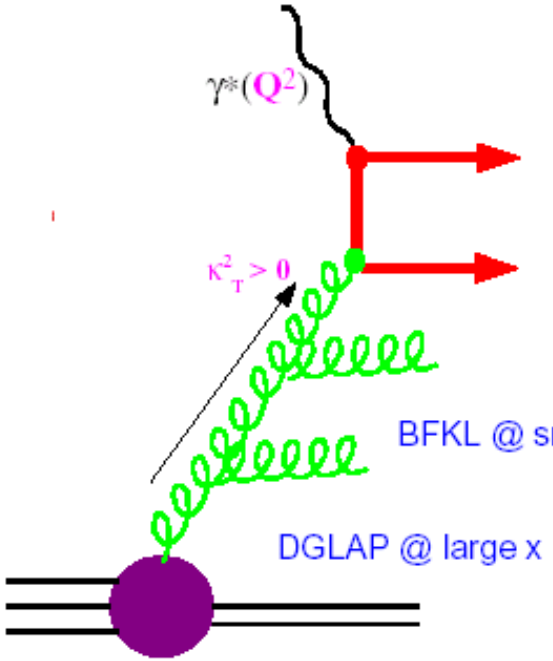
ARIADNE



Colour Dipole Model
Emission from independent dipoles produces
no k_t-ordering

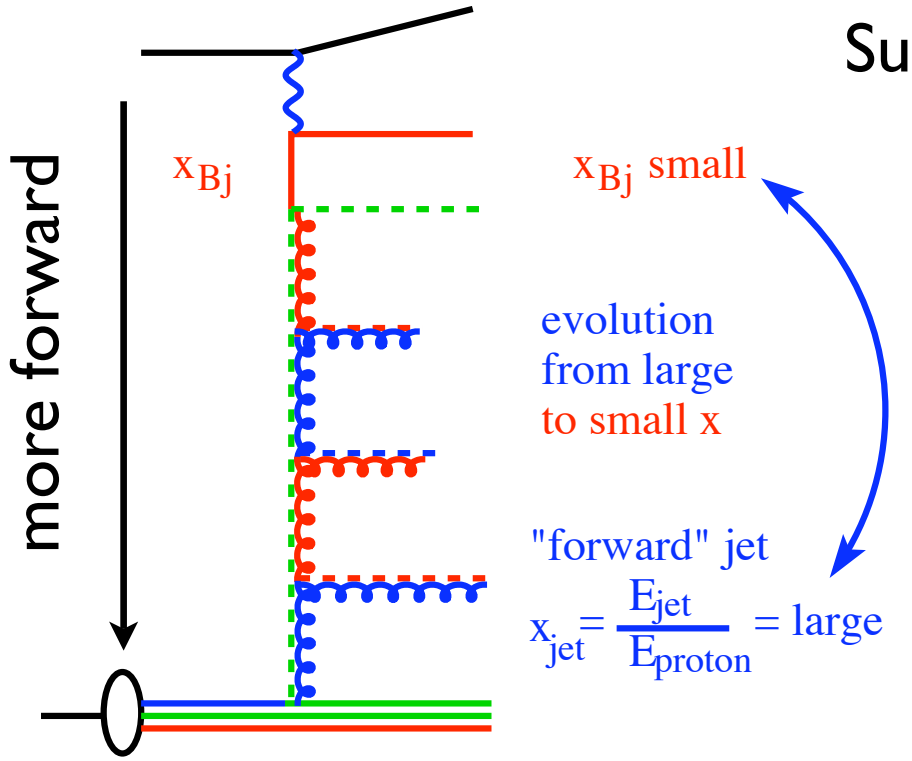
CCFM

CASCADE



'k_t-factorisation'

Enhancing non-DGLAP Parton Emmisions



Suppress DGLAP $P_{t,jet}^2 \sim Q^2$

Opens up phase space
to BFKL type emissions
$x_{jet} >> x_{bj}$

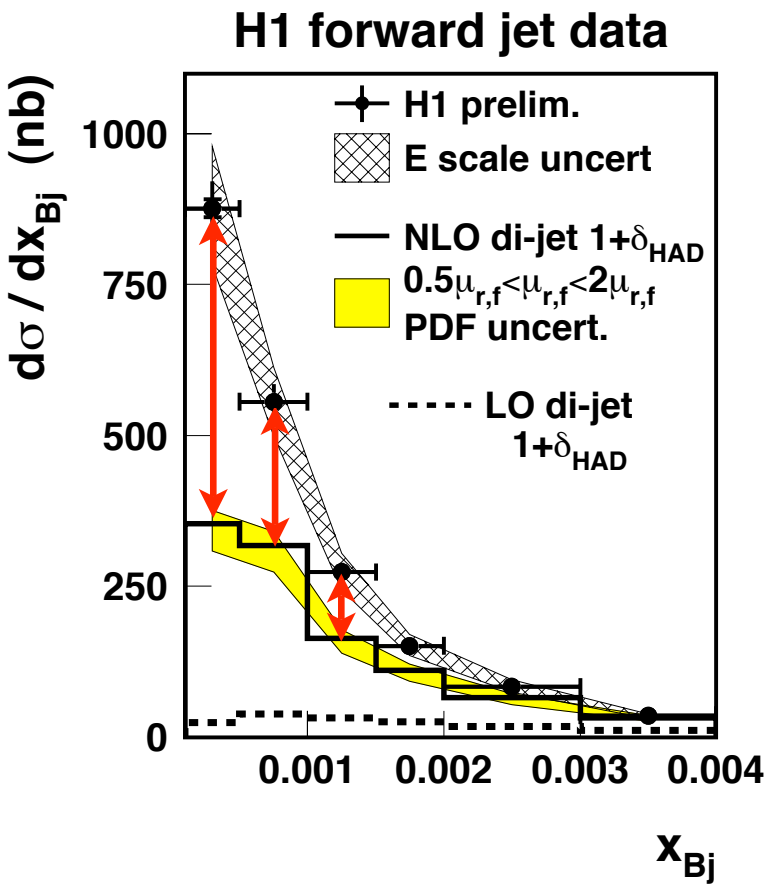
Forward Jet takes large
fraction of proton
momentum

kinematic acceptance $x_{bj} \sim 10^{-4}$, $\theta_{jet(lab)} > 7°$, $\eta_{jet} < 3.0$

Event selection
$E_{e'} > 10$ GeV $156° < \theta_{e'} < 175°$ $0.1 < y < 0.7$ $0.0001 < x_{bj} < 0.004$ $5\ \text{GeV}^2 < Q^2 < 85\ \text{GeV}^2$
$p_{t,jet} > 3.5$ GeV $7.0° < \theta_{jet(lab)} < 20°$ $x_{jet} > 0.035$

Inclusive kt jet algorithm in Breit frame

Inclusive Forward Jet Production



$0.5 < p_{t,jet}^2 / Q^2 < 5$

NLO = DISENT

PDF = CTEQ6M

$\mu_r^2 = E_T^2$ of Jet

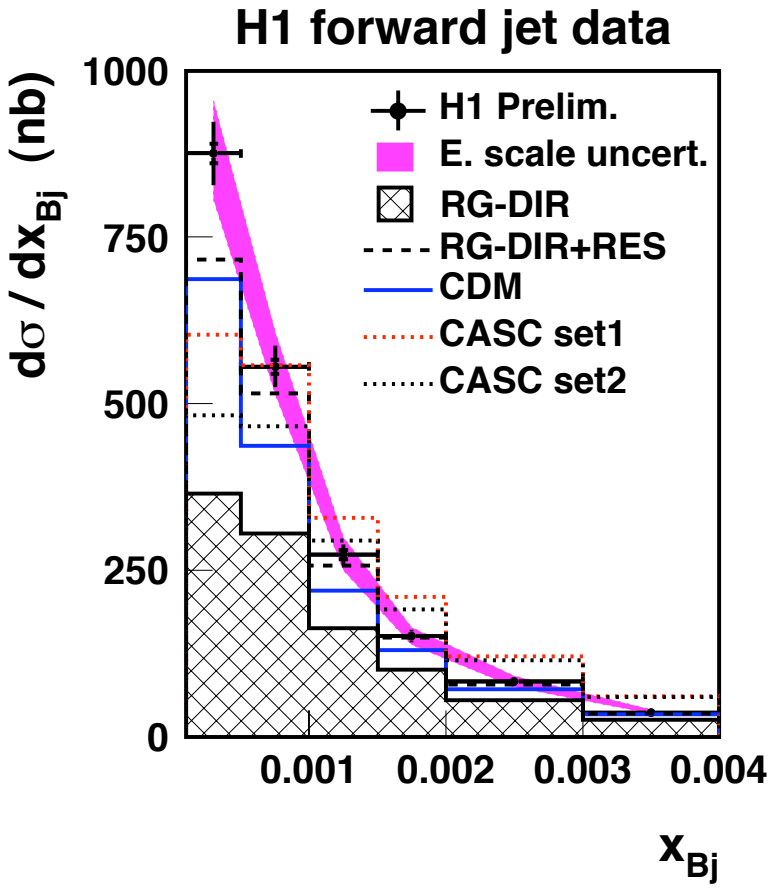
$\mu_f^2 = \langle E_T^2 \rangle = 45\ GeV^2$

NLO significantly below data

Is scale uncertainty large enough?

Large difference from LO to NLO predictions!

Inclusive Forward Jet Production



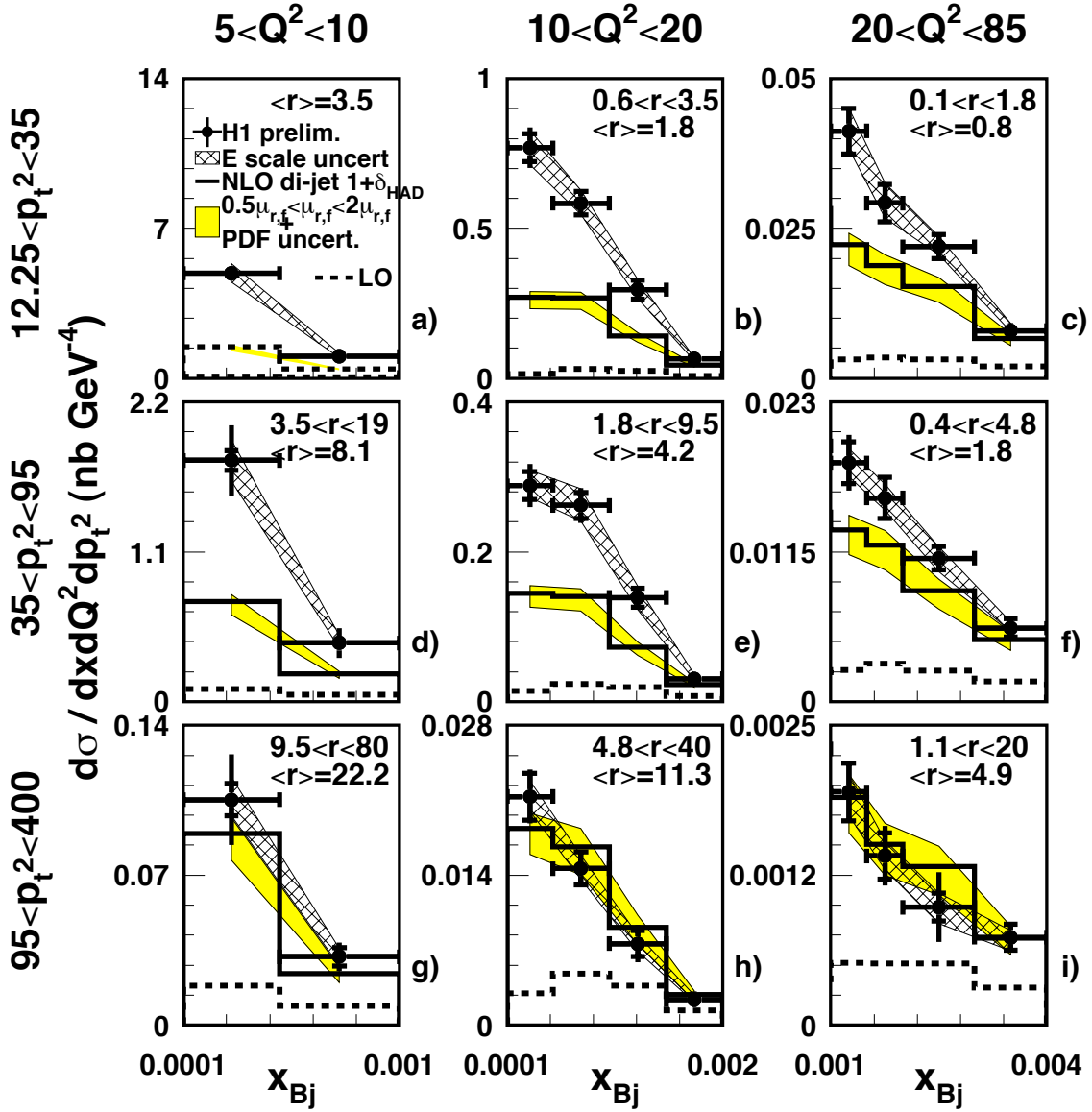
Significant improvement in RapGap (DGLAP) description if resolved photon interactions included

CDM similar model to RG-DIR+RES

Both still too low at low x_{bj}

CASCade shape wrong! Predictions sensitive to proton PDF used.

Triple Differential Cross Sections

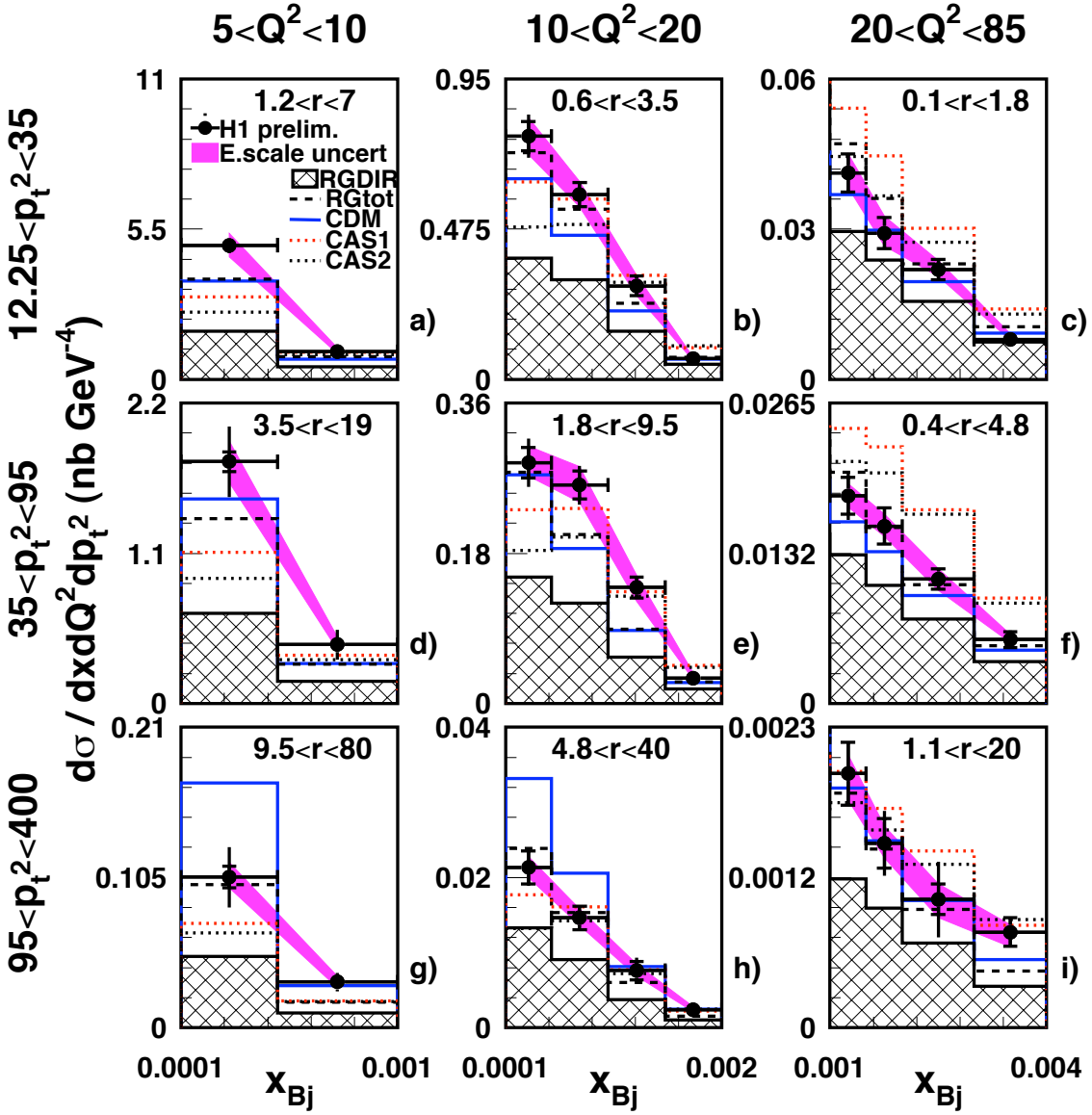


Good description at high Q^2, high $P_{t,jet}^2$ and high x_{bj}

Additional emissions needed at low Q^2, $p_{t,jet}^2$, x_{bj}

$r = p_{tjet}^2/Q^2$

Triple Differential Cross Sections



RG DIR Fails

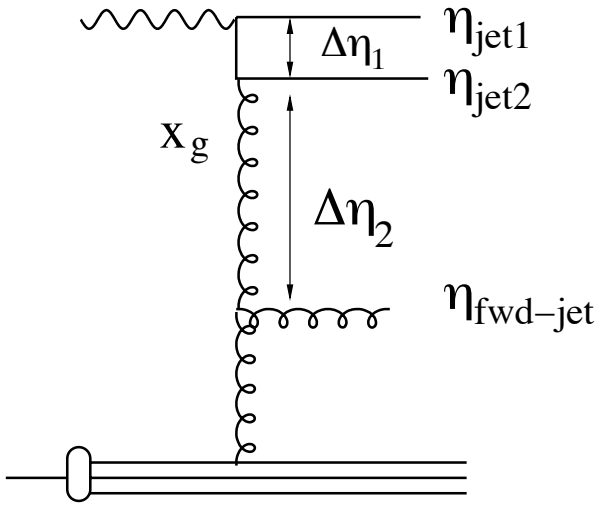
RG DIR+RES Better

CDM good problems at high $p_{t,jet}^2$

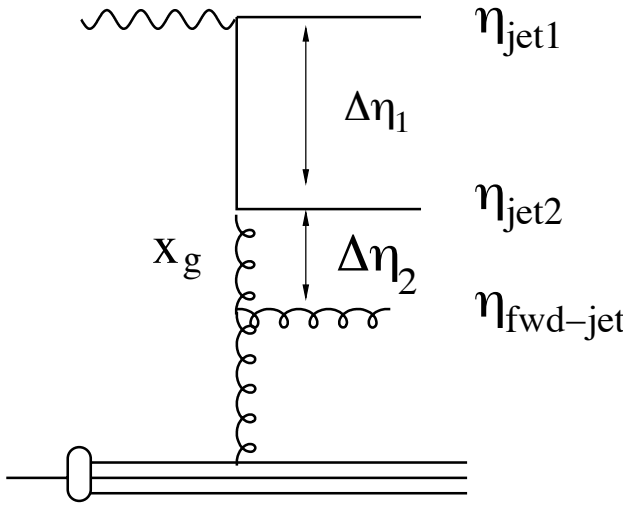
CAScade wrong shape, sensitivity to PDF

Forward Jet + Dijet

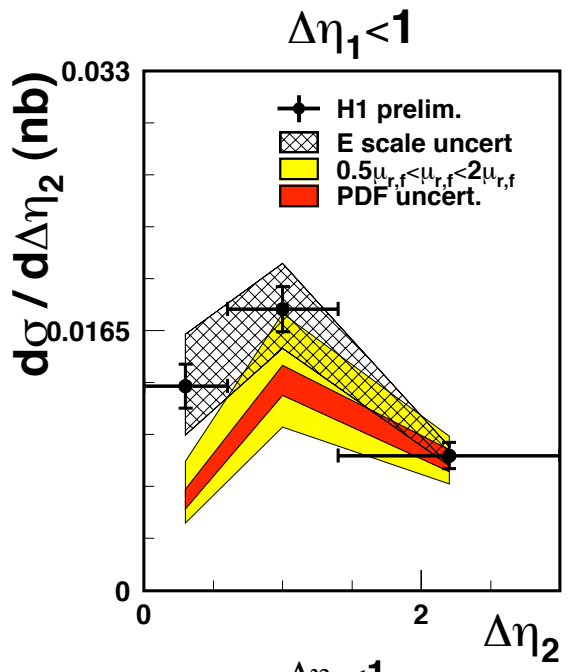
Two central jets (p_t > 6GeV) + Forward Jet



$\Delta\eta_1 < 1$,
x_g small, $\Delta\eta 2$ large,
room for BFKL ladder

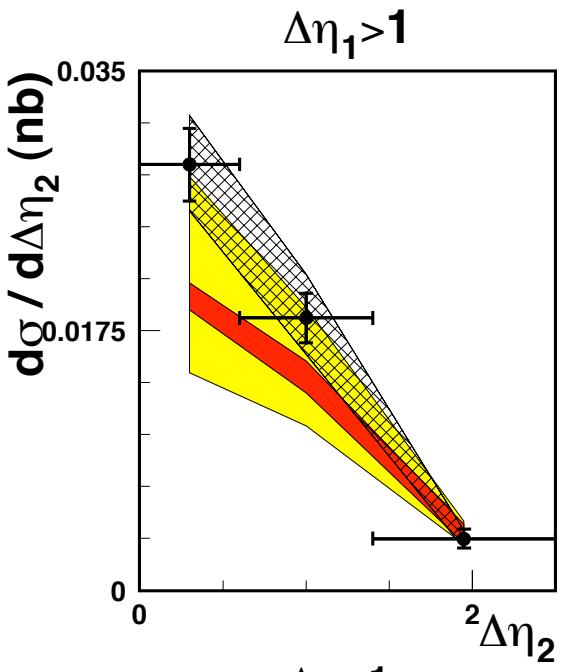


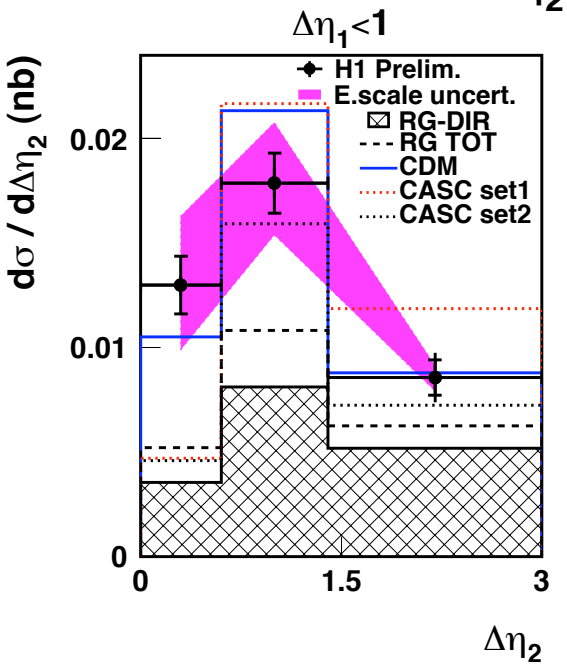
$\Delta\eta > 1$,
$\Delta\eta 2$ small, shorter
ladder, less BFKL like



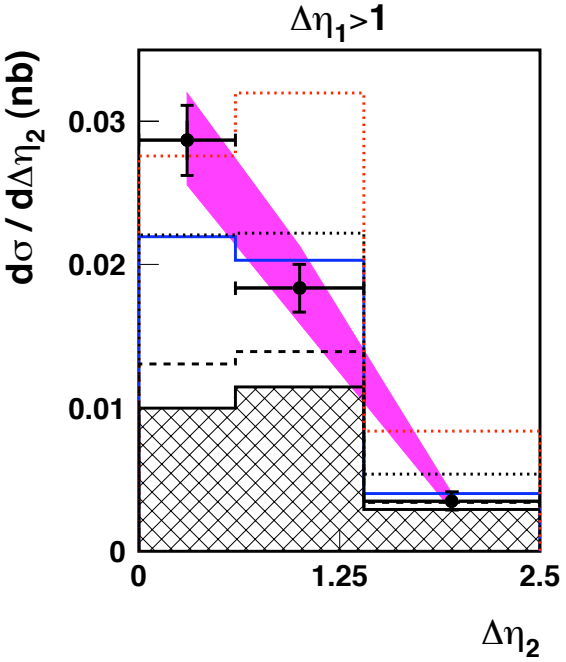
3 jet predictions from NLOJET++

scale uncertainties large

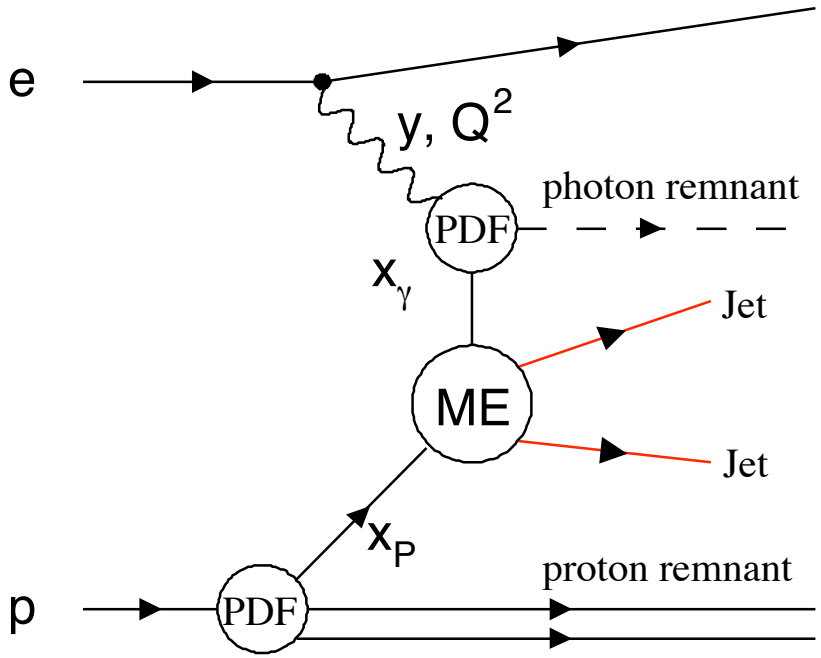




no model able to work in all phase space



Photoproduction of Dijets with high Transverse Momenta at HERA



Photoproduction

$Q^2 < 1$ GeV^2

Experimentally
no electron seen

$x_\gamma < 0.8 \rightarrow$ resolved

$x_\gamma > 0.8 \rightarrow$ direct

$$x_p = \frac{1}{2E_p} \sum_{i=1}^{2} p_{t,i} e^{+\eta_i} \qquad x_\gamma = \frac{1}{2yE_e} \sum_{i=1}^{2} p_{t,i} e^{-\eta_i}$$

QCD Models

PYTHIA 6.1
Born level QCD matrix elements of hard processes
+ minimum p_t cutoff
+ LO proton (CTEQ5L) PDF
+ photon (GRV-LO) PDF
+ leading log parton shower models
+ multiple interactions + string hadronisation

only contain $2 \rightarrow 2$ photoproduction processes
have to apply scale factor 1.2 (1.55 for HERWIG)

Only PYTHIA shown, HERWIG very simmilar

NLO Calculations

pQCD NLO jet cross sections on
parton level obtained from programs
by Frixione + Ridolfi

proton PDF = CTEQ6M
photon PDF = GRV-HO

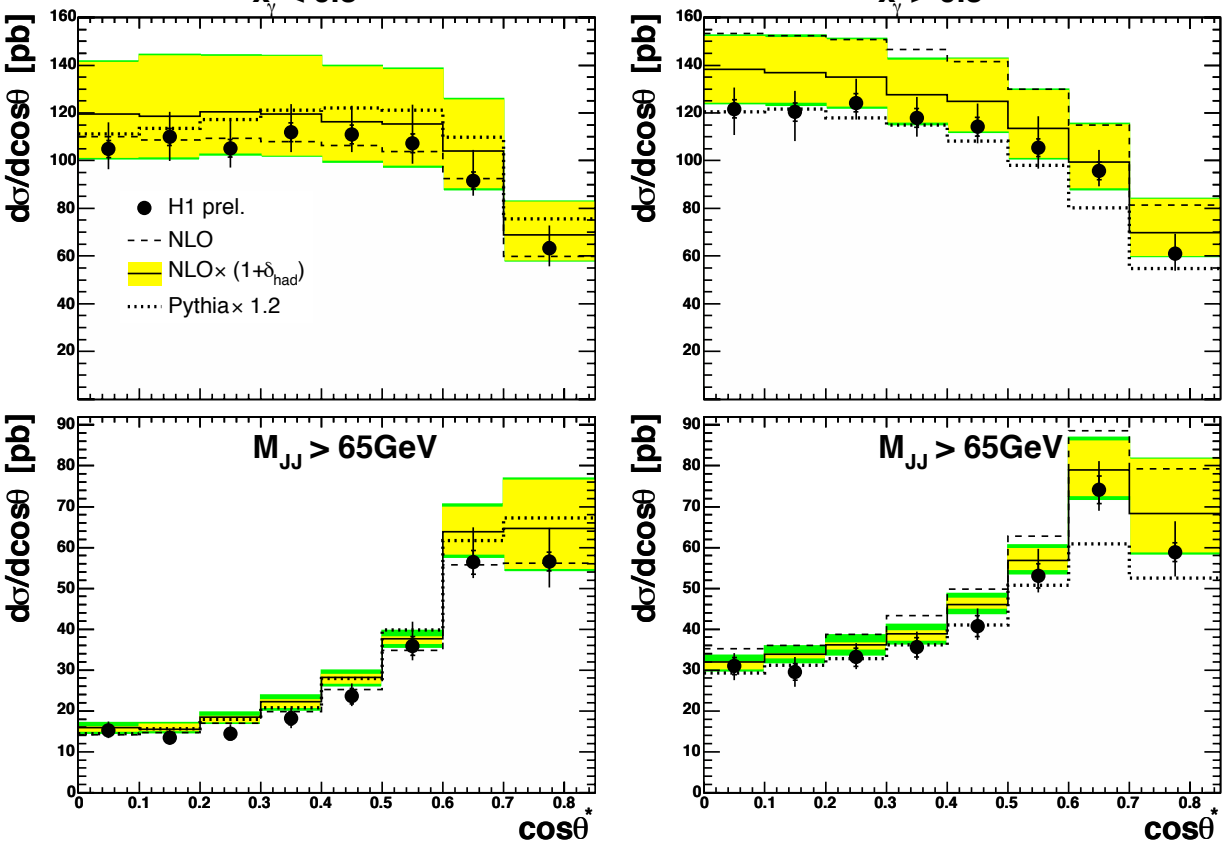
Factorisation and renormalisation scale (μ_f μ_r) set to
sum of pt of outgoing partons /2

Hadronisation correction (δ_{had}) from Monte Carlo

Event Selection
$\lvert ZVTX \rvert < 35$ cm $p_{t,miss} < 20$ GeV non-ep topological background finder
no identified scattered electron jet mass > 2 GeV Not (Jet in φ crack and jet size < 0.05)
$p_{t,jet} > 25$ GeV $p_{t,jet2} > 15$ GeV $-0.5 < \eta_{jet} < 2.75$
$0.1 < y_{JB} < 0.9$

cosθ*

$x_\gamma < 0.8$ $x_\gamma > 0.8$



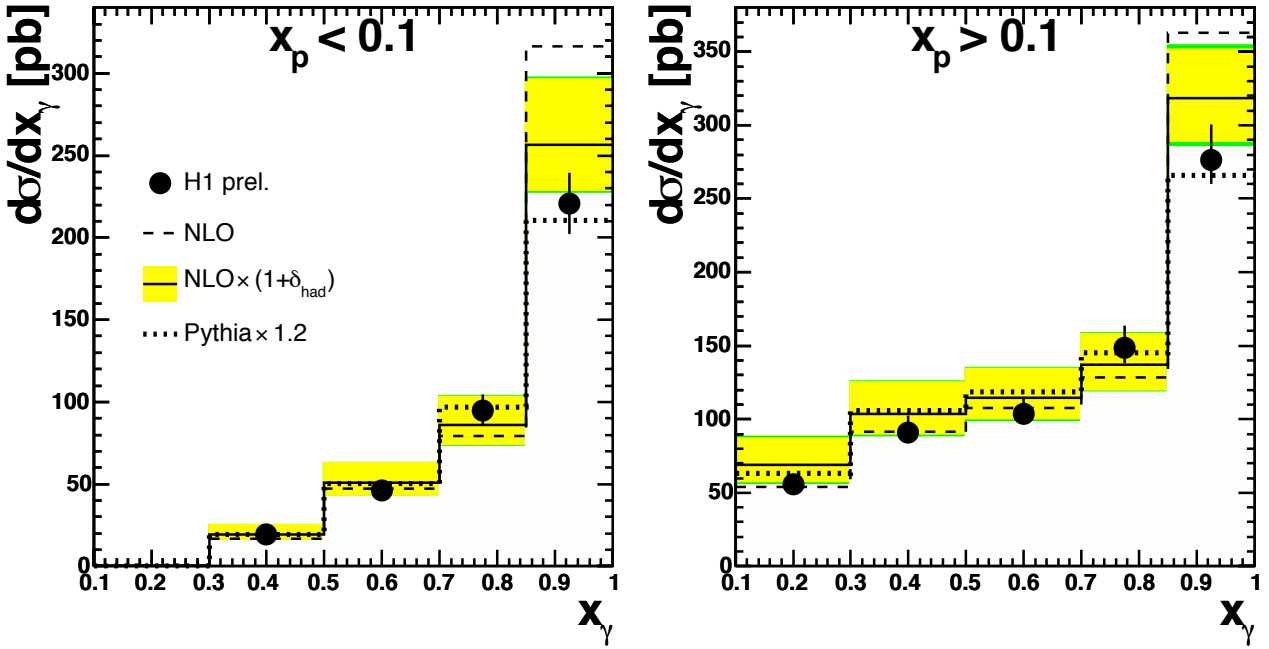
$M_{jj} > 65$ GeV

RES ∝ $(1-\cos\theta)^{-2}$ DIR ∝ $(1-\cos\theta)^{-1}$

$\cos\theta^* = |\tanh(\eta_1-\eta_2)/2|$

Scale Scale+PDF

x_γ

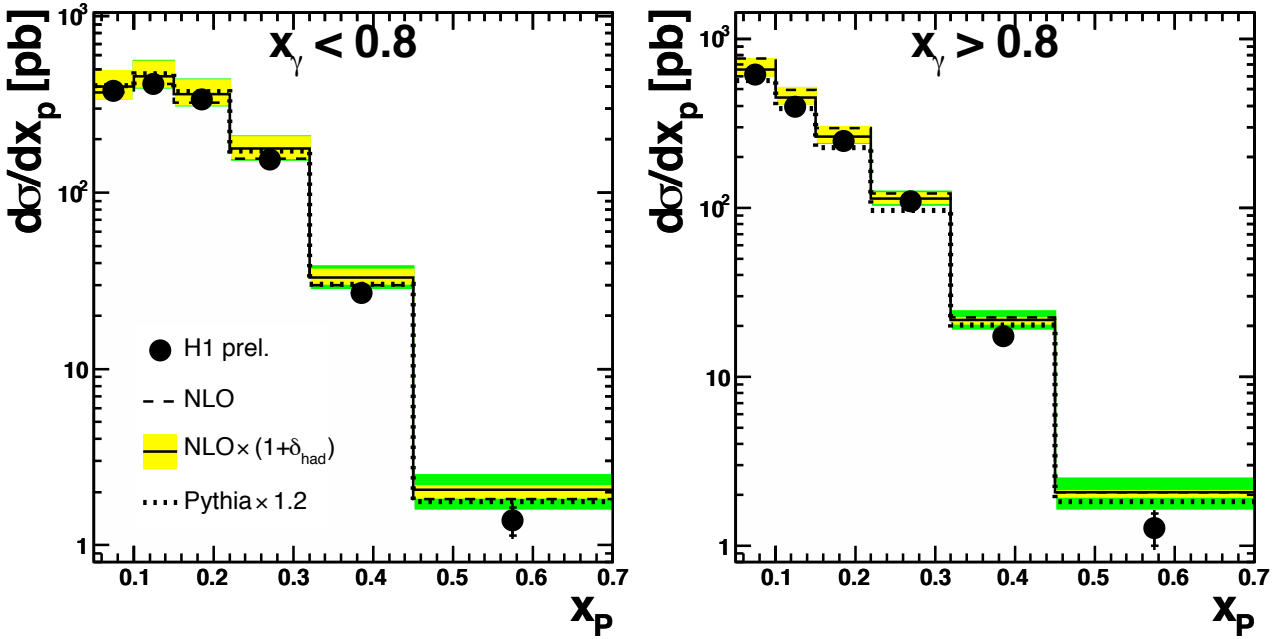


photon - gluon

photon - quark

nlo dominated by the scale uncertainty

x_p

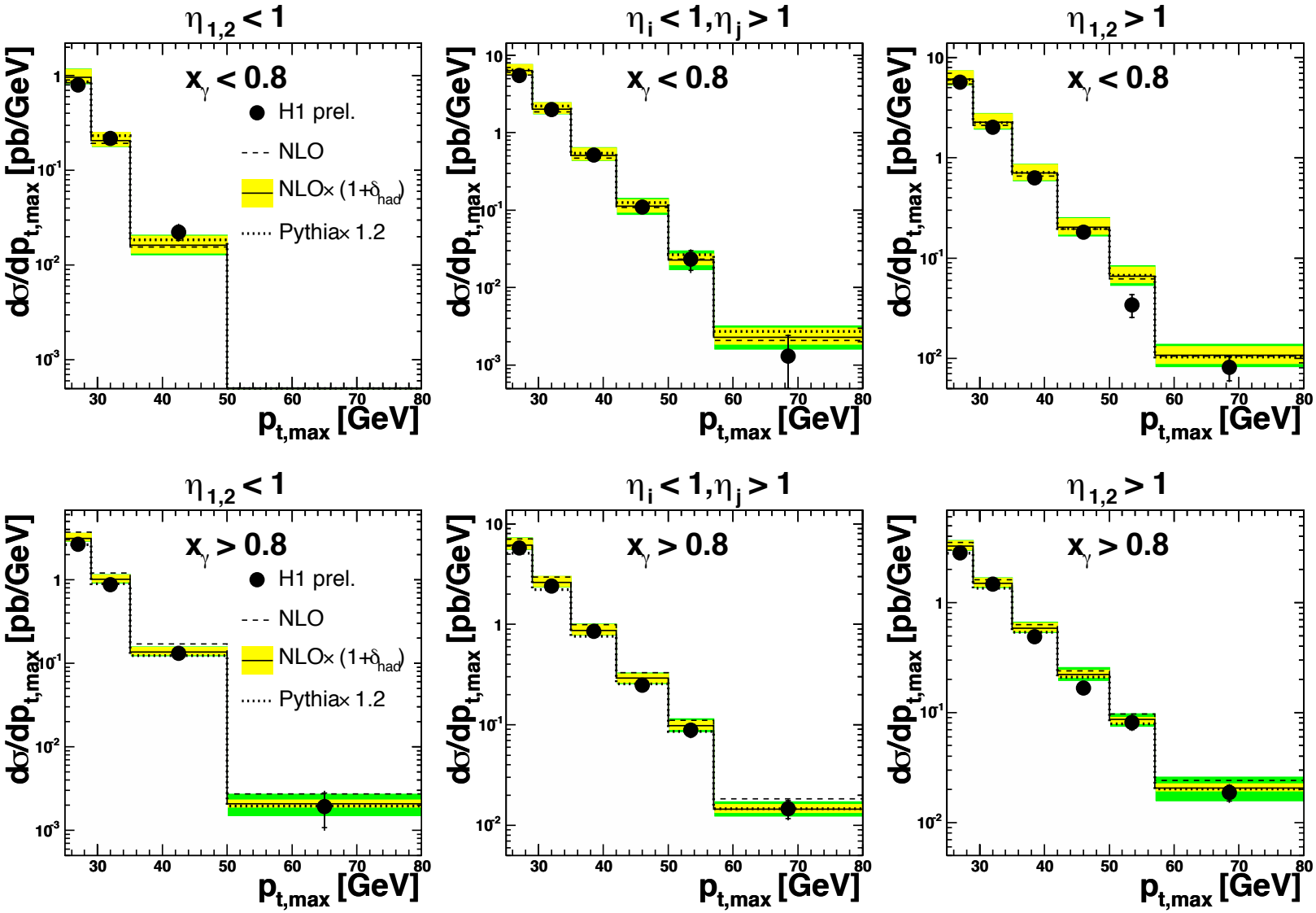


high x_p sensitive to proton PDF

high x_p - high jet η

scale uncertainty smallest

$p_{t,max}$


$\eta_{1,2} < 1$
$x_\gamma < 0.8$
H1 prel.
NLO
NLO× (1+δ_{had})
Pythia× 1.2
$d\sigma/dp_{t,max}$ [pb/GeV]
$p_{t,max}$ [GeV]
$\eta_i < 1, \eta_j > 1$
$x_\gamma < 0.8$
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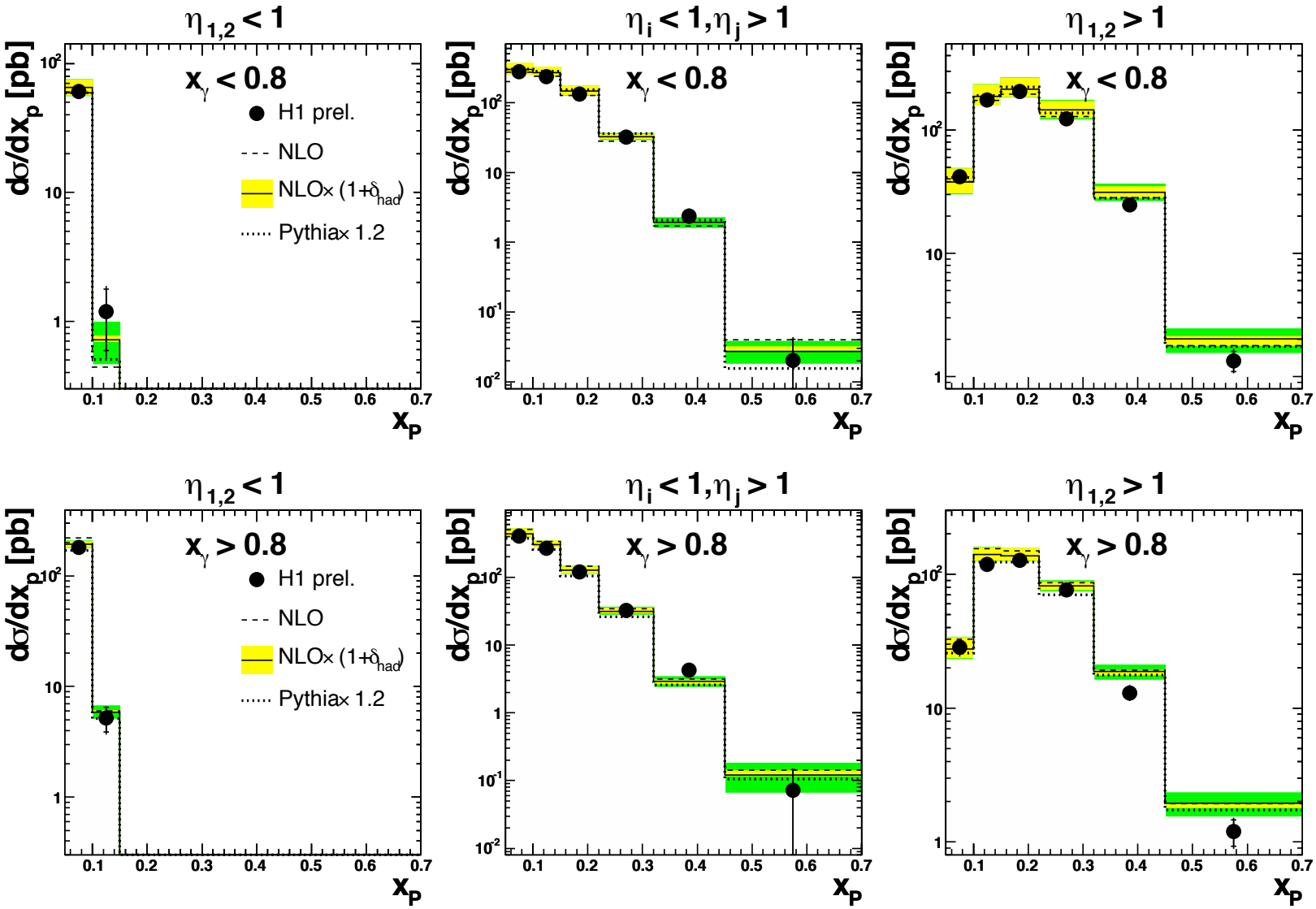
x_p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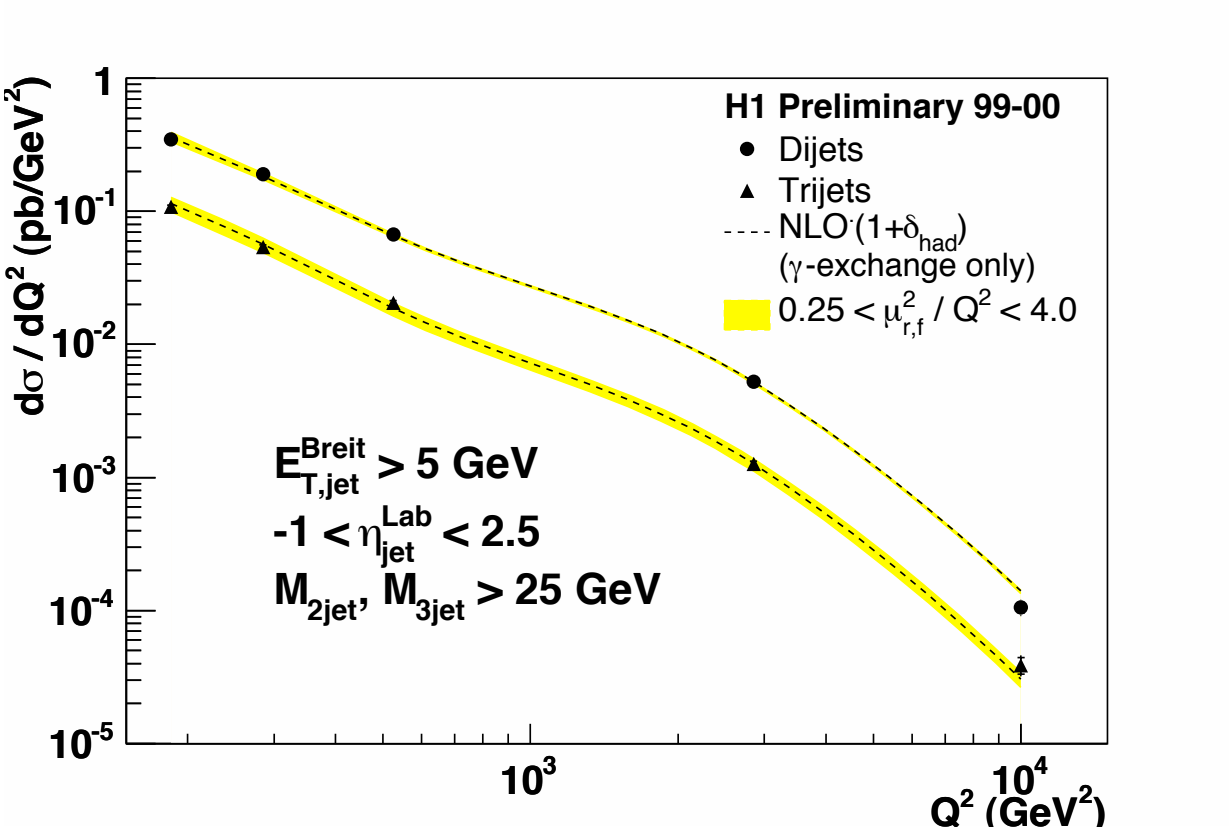
$d\sigma/dx_p$ [pb]
x_P
$\eta_{1,2} > 1$
$x_\gamma > 0.8$
$d\sigma/dx_p$ [pb]
x_P

Multi-jet production in high Q2 neutral current deeply inelastic scattering at HERA and determination of α_s

H1prelim-05-033



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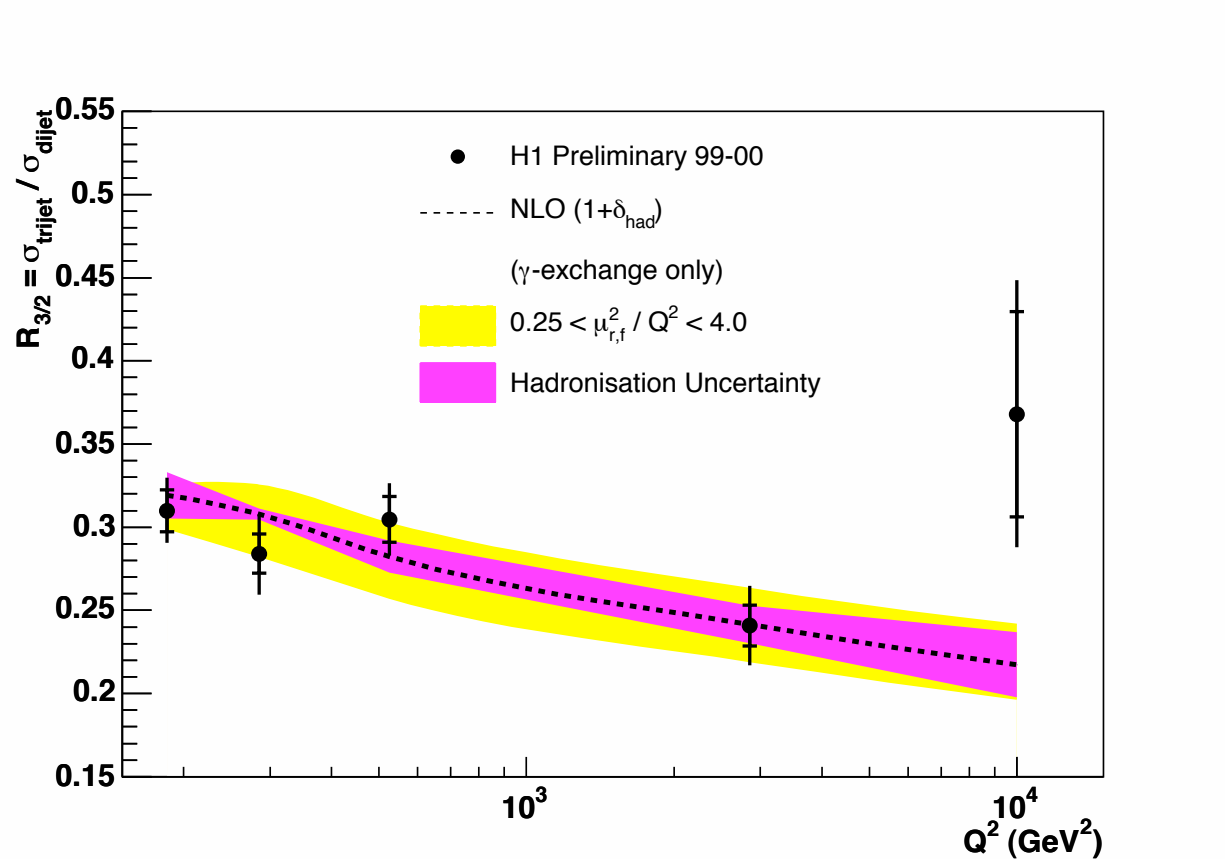
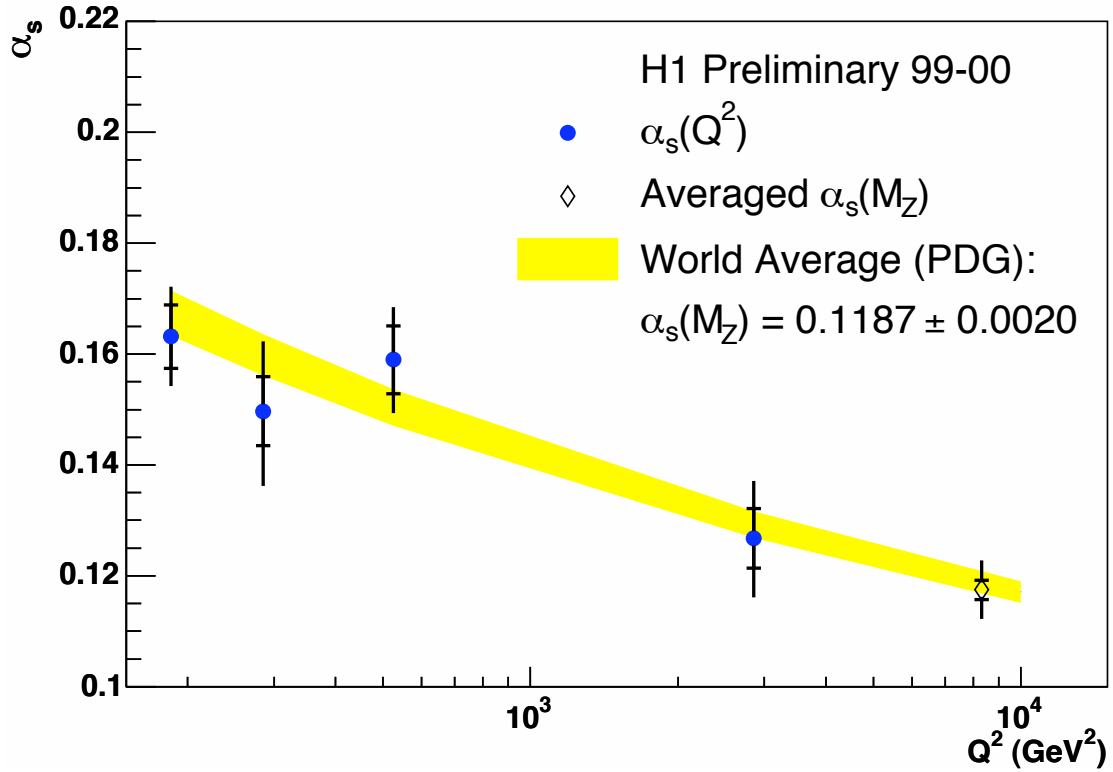
H1prelim-05-033



Multi-jet production in high Q2 neutral current deeply inelastic scattering at HERA and determination of α_s

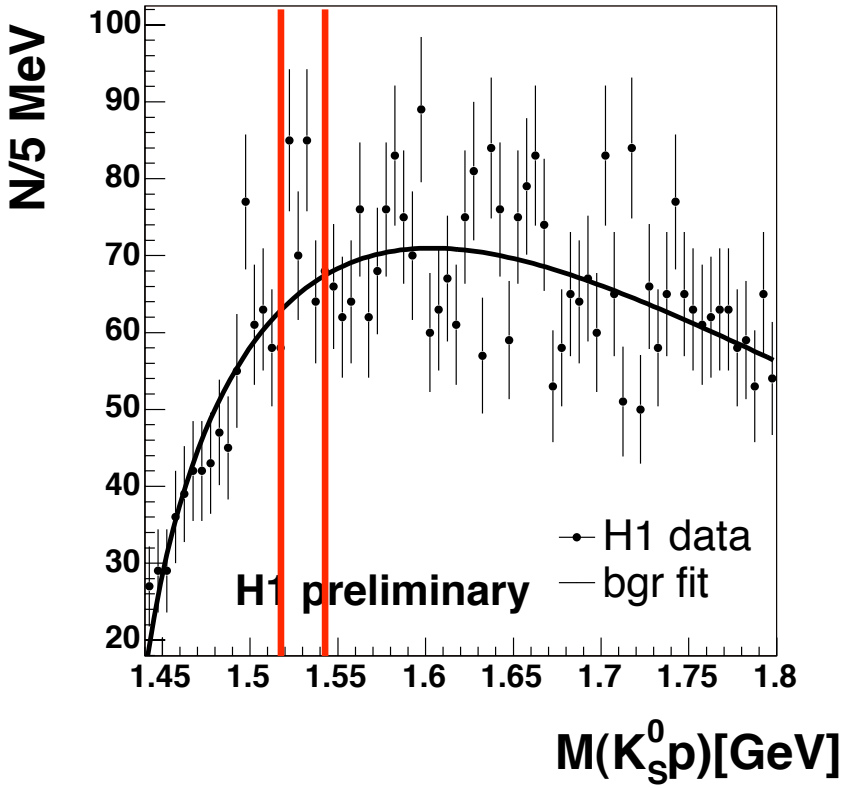
H1prelim-05-033



$\alpha_s(M_Z) = 0.1175 \pm 0.0017$ (stat.) $\pm$ 0.0050 (syst.)
{+0.0054}{-0.0068} (th.)

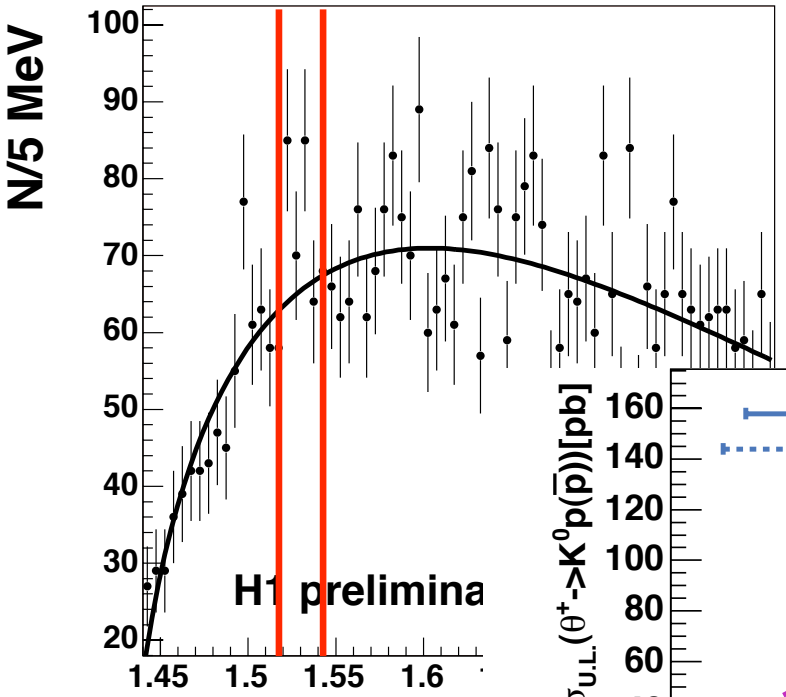
H1 Search for a Narrow Baryonic Resonance Decaying to K^0_s p(p)

H1prelim-05-031

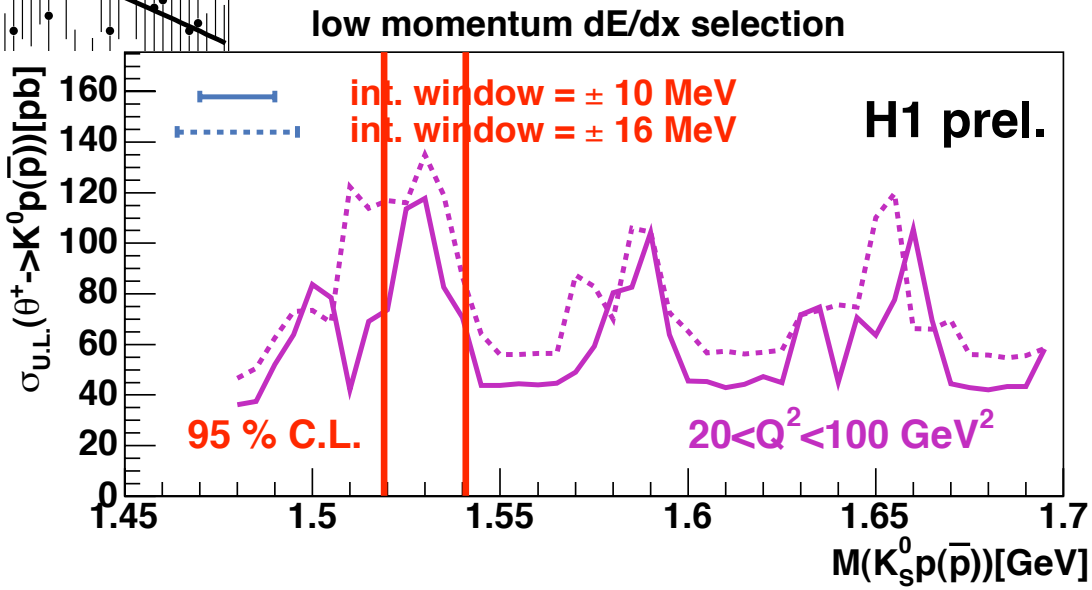


H1 Search for a Narrow Baryonic Resonance Decaying to K^0_s p(p)

H1prelim-05-031



Upper limit on cross section at 1520MeV is roughly 100pb, does not exclude ZEUS observation

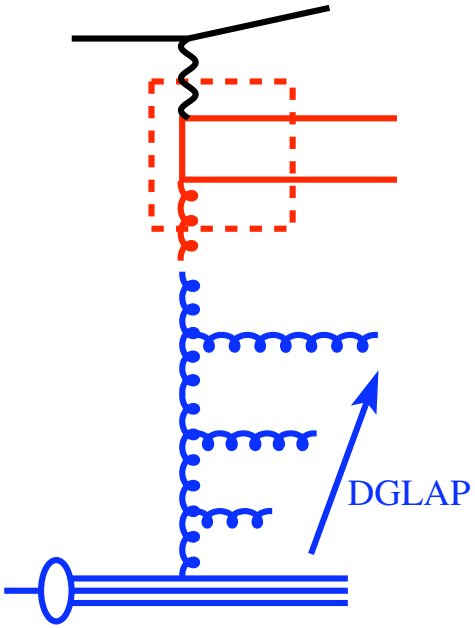


Summary

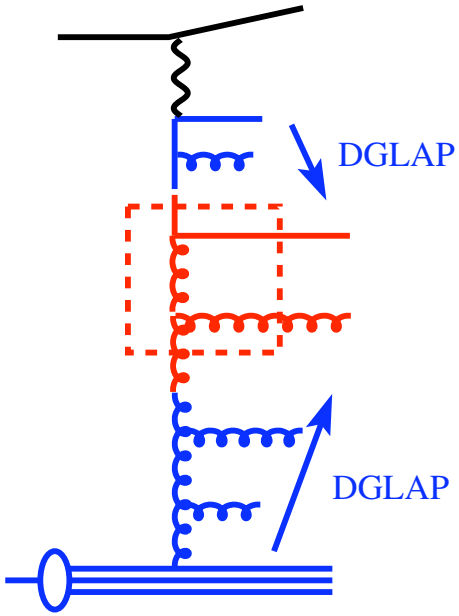
- Studies of Forward Jets show need for additional terms beyond present collinear DGLAP
- New results on the photoproduction of high Et dijets, sesitive to the proton PDF, have been made.

Parton Dynamics in DIS

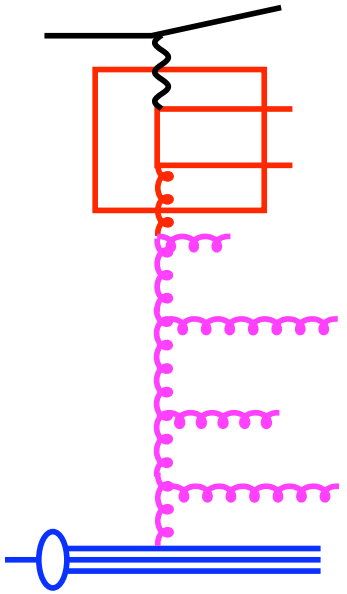
DGLAP direct photon



DGLAP resolved photon



CCFM or BFKL



Strong ordering in k_t of parton emissions

angular ordering of parton emissions