Review of Power Corrections in DIS

FRIF Power Corrections Workshop 06, Paris

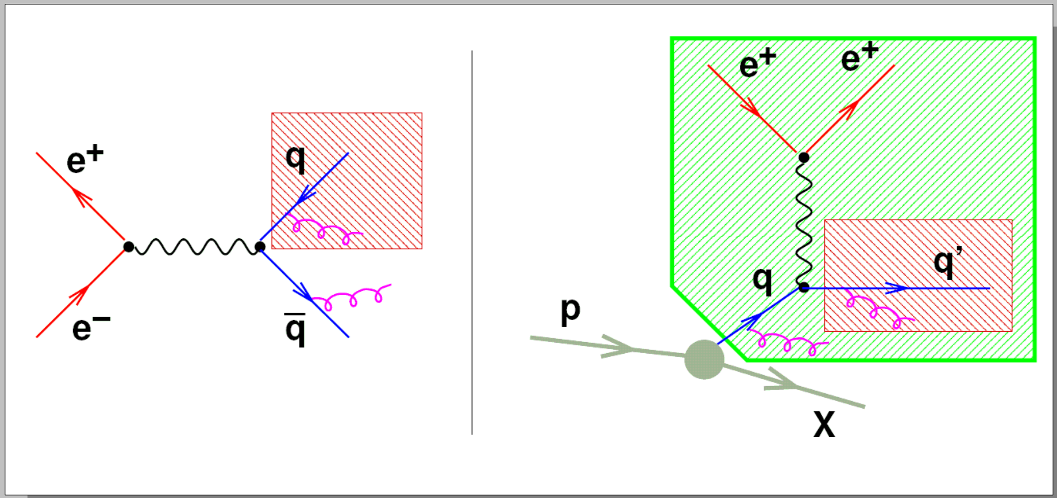
Thomas Kluge, DESY

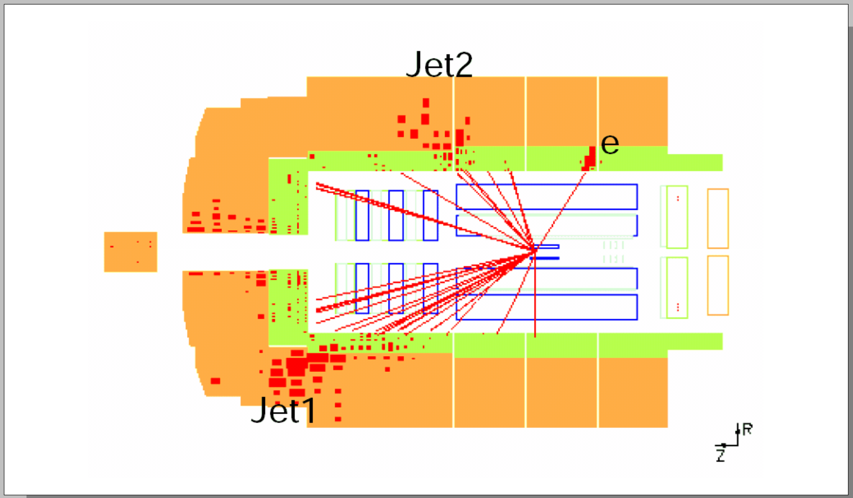
- some history
- peculiarities of event shapes in DIS
- mean values of 2-jet shapes
- distributions of 2-jet shapes
- distributions of 3-jet shapes

History of Power Corrections in DIS

- 95: DIS Paris - Brian Webber presents ‹F›+PC for DIS
- 96: DIS Rome - First H1 data ‹F›(Q), waiting for pQCD calculation MEPJET,DISENT,DISASTER++
- 97: H1 publishes $\langle\tau\rangle$,$\langle\tau_c\rangle$,‹B›,$\langle\rho\rangle$ - universal α_0 prediction for B not confirmed PLB406(1997)256
- jet broadening revisited by theory, 2-loop corrections, Milan factor: Dokshitzer, Webber, Dasgupta, Salam,...
- 99: H1 publishes mean values- still large spread of $\alpha_s(m_Z)$, massless observables, first tries with spectra EPJC14(2000)255
- 01: HEP Budapest - Mrinal Dasgupta: resummed spectra for DIS
- 02: ZEUS results on mean values EPJC27(2003),531
- 03: EPS Aachen - prel. H1 spectra, first 3-jet data (K_{out}, χ)
- 04: HEP Beijing - prel. ZEUS spectra, 3-jet data
- 12/2005: H1 results on mean values and distributions, hep/ex 0512014

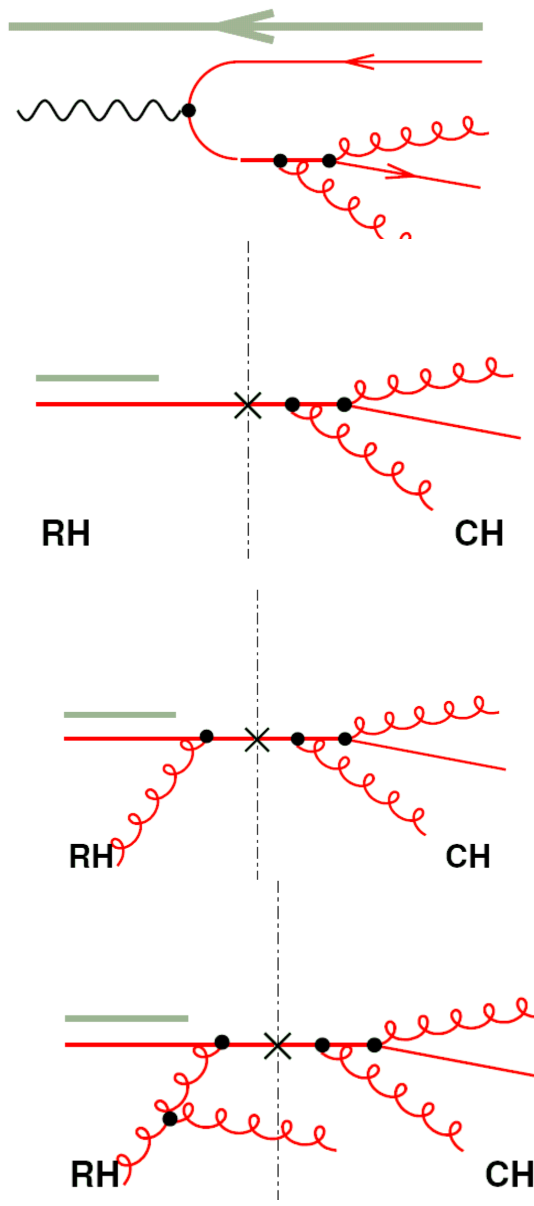
Eventshapes in DIS at HERA





- t-channel scattering
- $\sqrt{s}$ <=> $\sqrt{Q^2}$ Q^2=sxy variable, here: Q=5..115 GeV
- initial state: not vacuum, factorise into pdfs
- outgoing parton ±resembles 1/2 of e^+e^- event
- separate low momentum proton remnant -> Breit frame

The Breit Frame



- brick wall frame
- define hemispheres (CH: $\eta<0$)
- event shapes defined on particles in current hemisphere
- emmisions in remnant hemisphere
  - some event shapes sensitive through recoil (Global observables)
  - RH partons may leak into CH
- avoid IR sensitivity due to near empty CH by E_{min} requirement, e.g. $E_{CH}>0.1\cdot Q$
- jet rates: defined for both hemispheres

Observables studied

$$T_C = \max_{\vec{n}_T} \frac{\sum |\vec{p}_h \cdot \vec{n}_T|}{\sum |\vec{p}_h|}$$

$$\rho = \frac{(\sum E_h)^2 - (\sum \vec{p}_h)^2}{(2 \sum |\vec{p}_h|)^2}$$

$$C = \frac{3}{2} \frac{\sum_{h,i} |\vec{p}_h||\vec{p}_i| \sin^2 \theta_{hi}}{(\sum |\vec{p}_h|)^2}$$

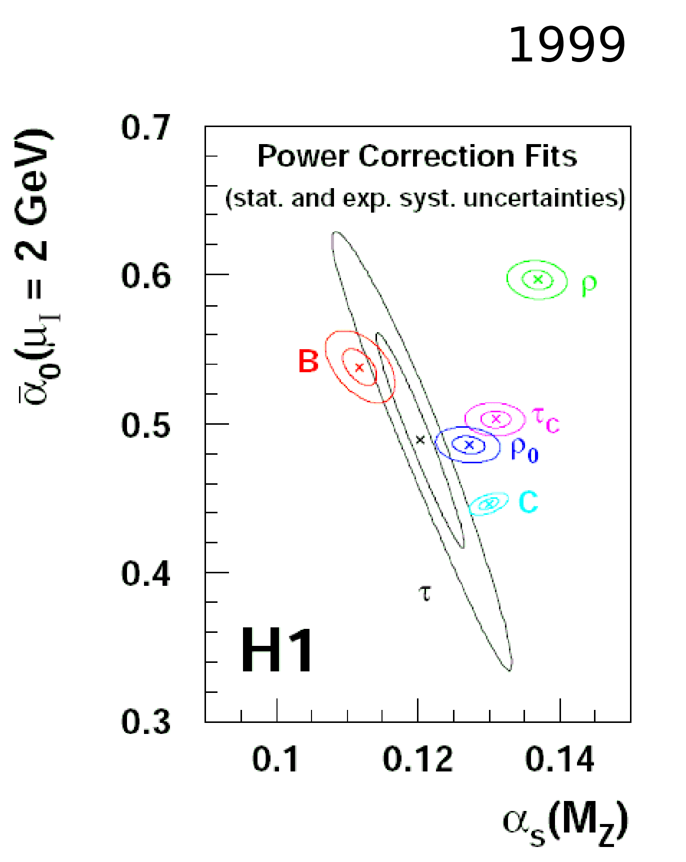
- defined wrt „own“ axis
- non-global observables
- insensitive to pdf

$$T = \frac{\sum |\vec{p}_{z,h}|}{\sum |\vec{p}_h|}$$

$$B = \frac{\sum |\vec{p}_{\perp h}|}{2 \sum |\vec{p}_h|}$$

- defined wrt virtual boson axis
- global observables
- more sensitive to pdf (and evolution)

Mass effects



- jet mass defined using E and p
- dependent on particle masses
- avoid by using massless scheme
- substitute E by |p|, ρ -> ρ_0
- mass effects are substantial
- residual effect on all variables
- in the following use ρ_0, but interesting topic in itself

Overview of Studies

MEAN VALUES

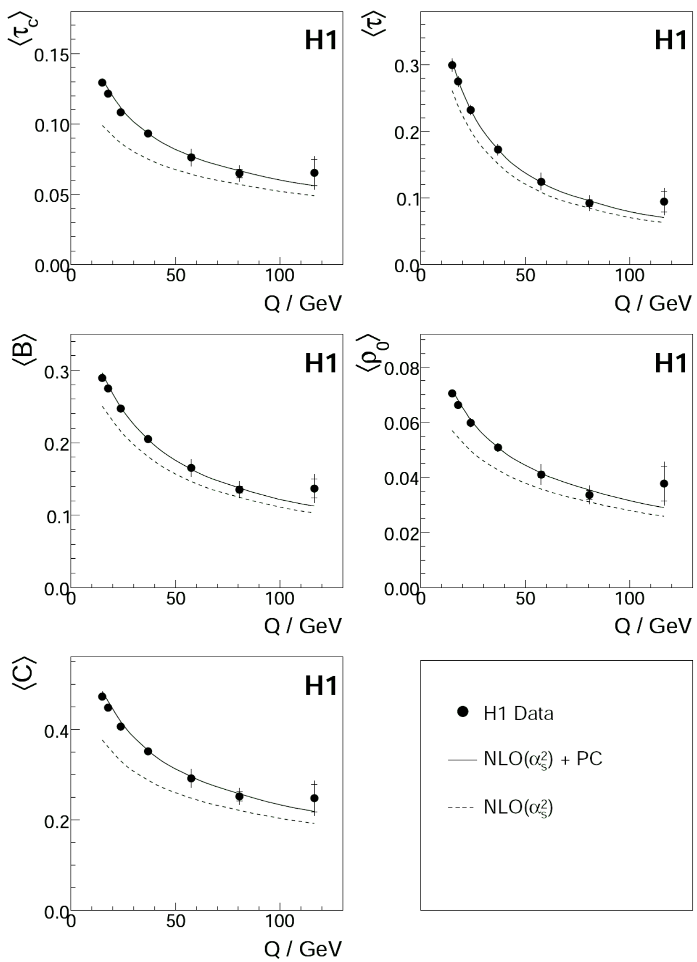
- 2-jet event shapes, NLO+PC
- jet rates, NLO(+PC)

DISTRIBUTIONS

- 2-jet event shapes, NLO+NLL+PC
- 3-jet event shapes, LO+NLL+PC
- jet rates, NLO

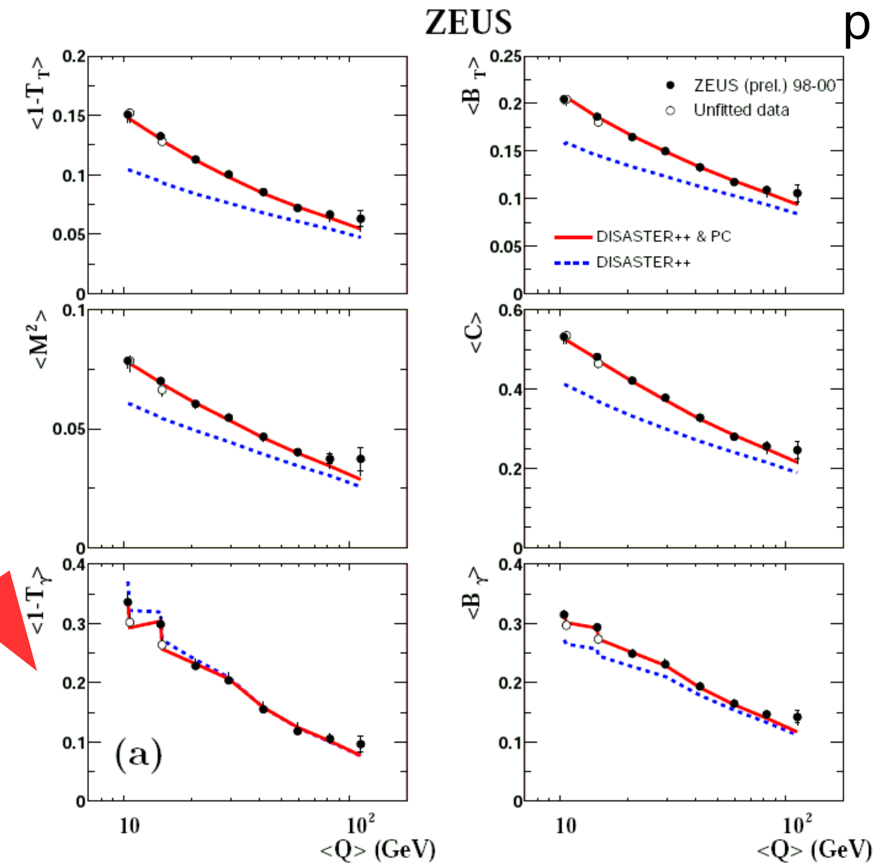
Mean Values

2005



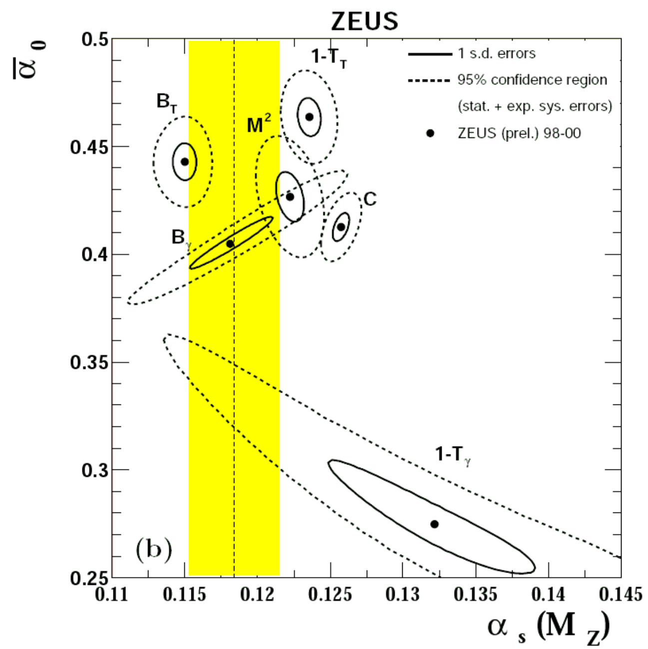
- 106pb^{-1}, 15<Q<116 GeV
- fit: DISASTER++ with PC
- power corrections >0

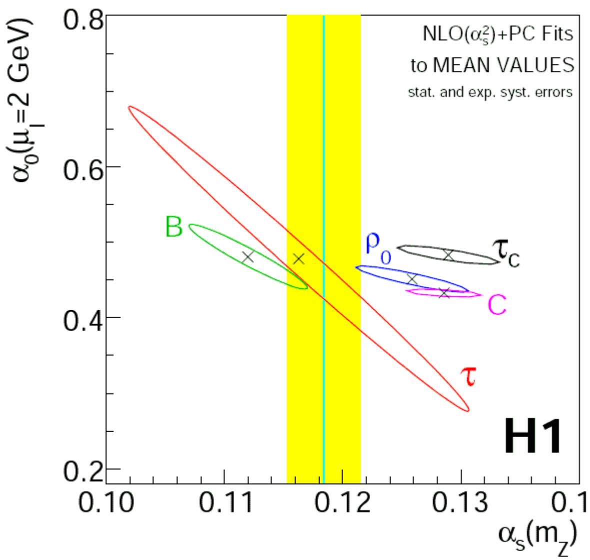
prel



- 82pb^{-1}, 10<Q<113 GeV
- fit: DISASTER++ with PC
- PC for γ-axis variables small, ≤ 0 for T_γ

QCD Fits to Mean Values

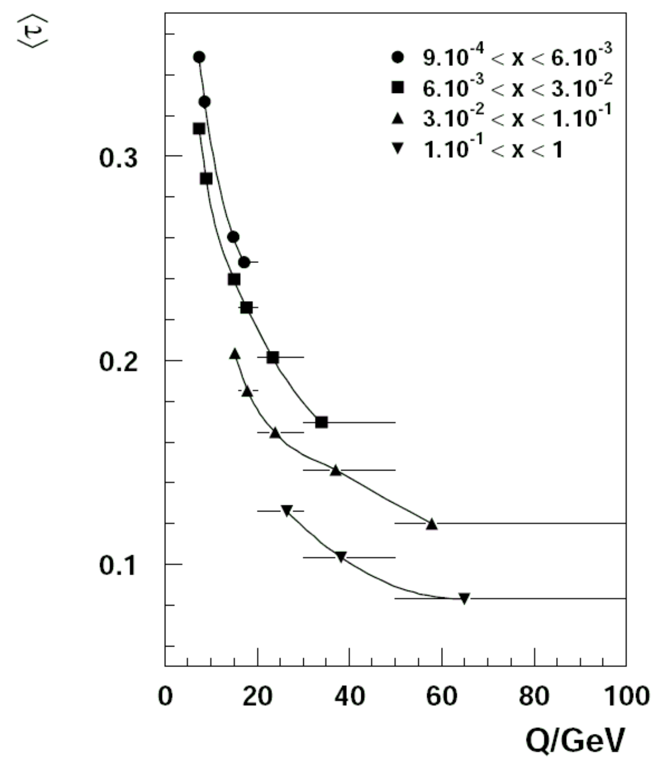




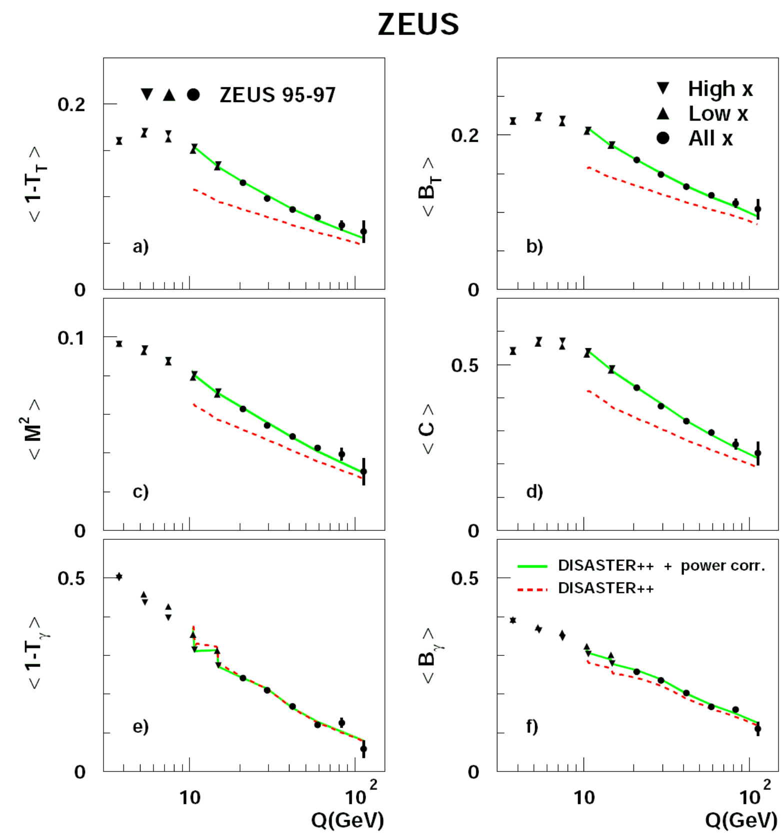
2005

- γ-axis thrust
  - large uncertainties
  - ZEUS: negative correction
- other: sensible values of α_0, universality at 10% level, H1 ~10% higher than ZEUS
- spread in α_s larger than exp. errors.
  - higher order pQCD needed?
- results consistent with 95-97 analyses
- exp. errors small
  - dominating systematic: elm. E-scale due to boost to the Breit system

x dependence

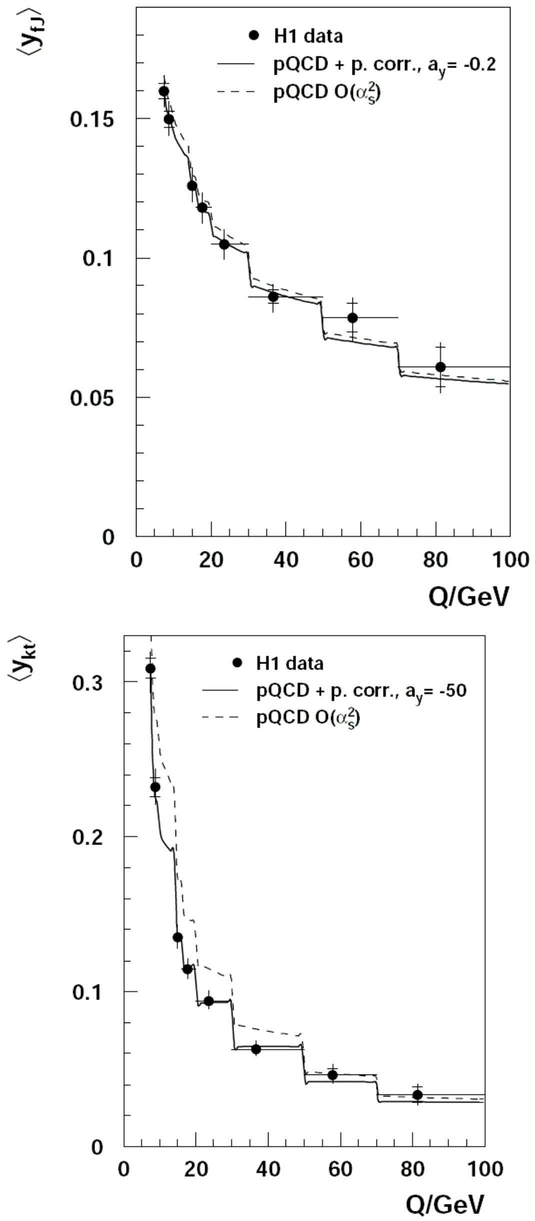


- γ-axis variables: dependence on Bjorken x due to pdf, largest for thrust
- H1 integrate over Q bin
- ZEUS: split high/low x



- 95-97: x-depence of α_0 seen for some variables
- not confirmed by new analysis

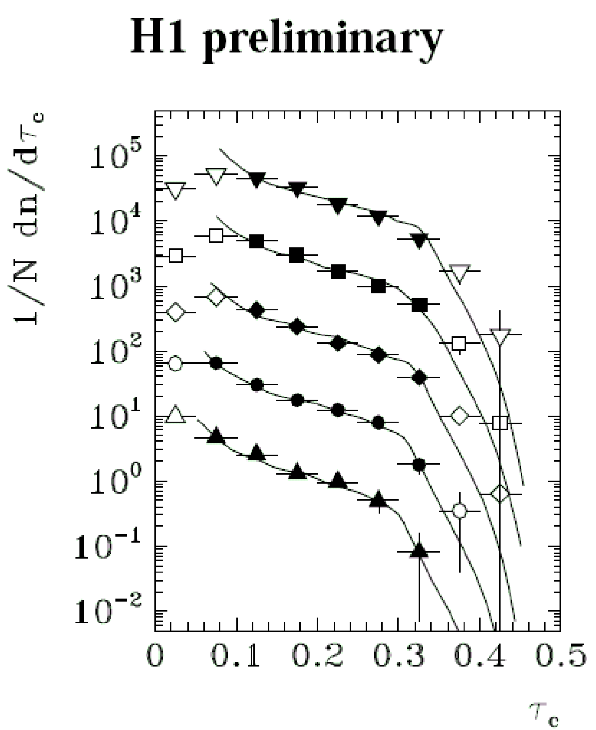
Mean Values Jet Rates



- jet rates: mean value of resolution y for 2+1->1+1 jets transition
- factorisable JADE y_{fJ}
  - p=1, a_f=1 (PC parameters)
  - compatible with pQCD alone
- Durham kt y_{kt}
  - p=2, a_f=? (PC parameters)
  - fit: a_f=-50
- no reasonable fits for (α_s,α_0)
- open question...

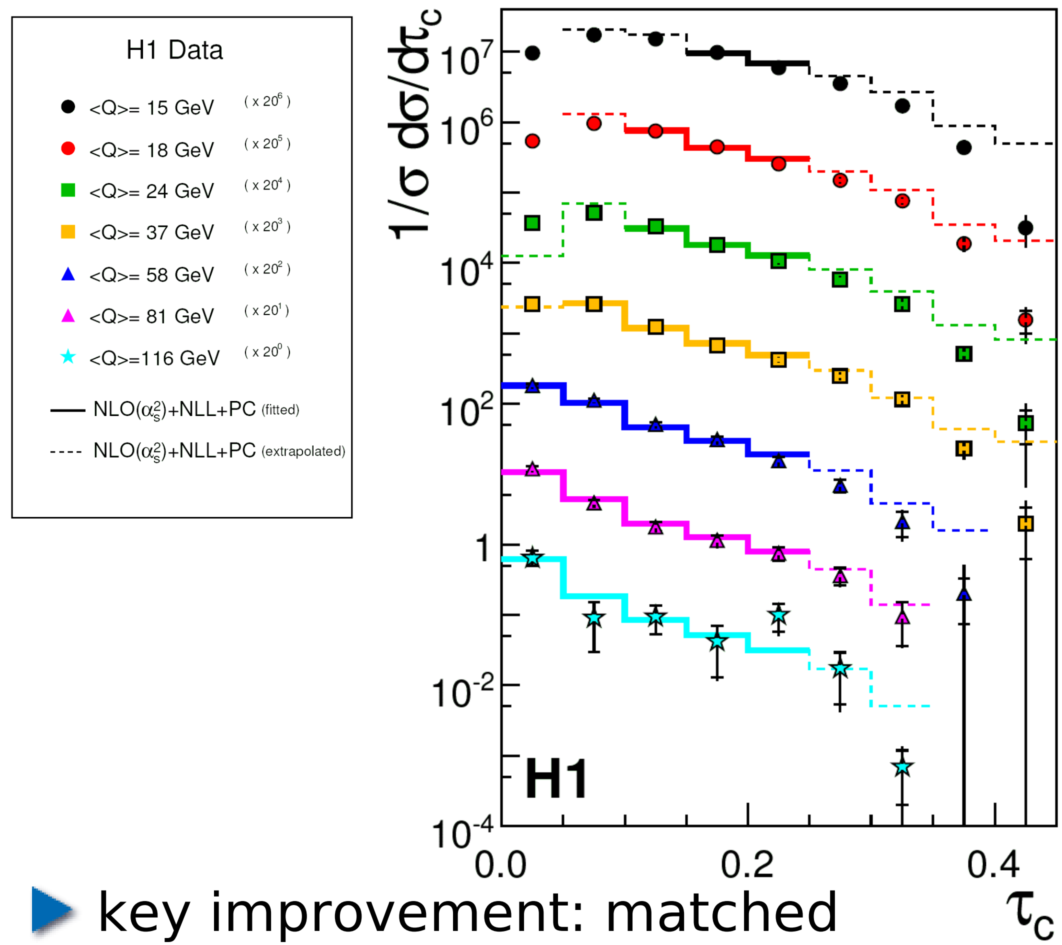
Distributions

1998



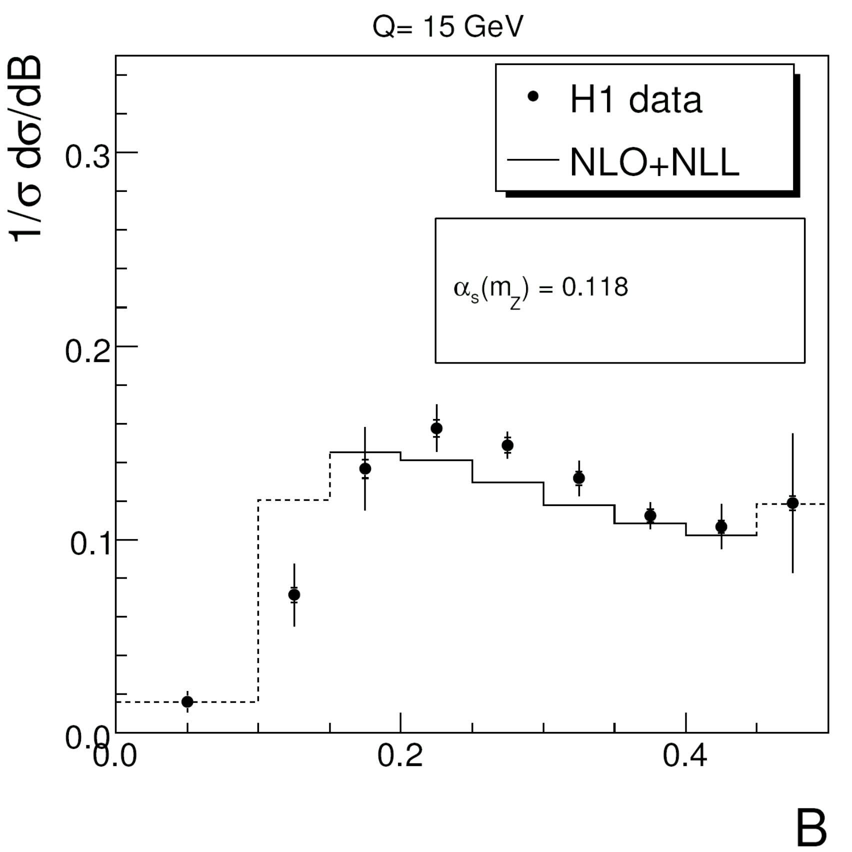
- no resummation
- description over limited range
- large values of (α_s,α_0) compared to mean values
- not feasible

2005

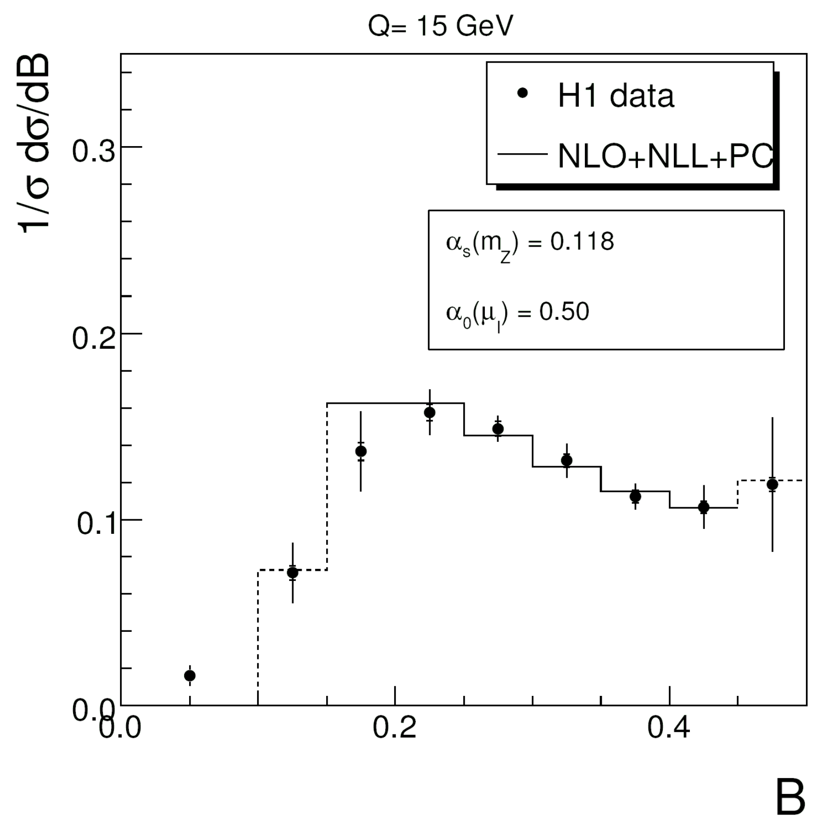


- key improvement: matched resummation via DISRESUM
- small errors: stat 1-10%
  syst 2-15%

Resummed Distributions

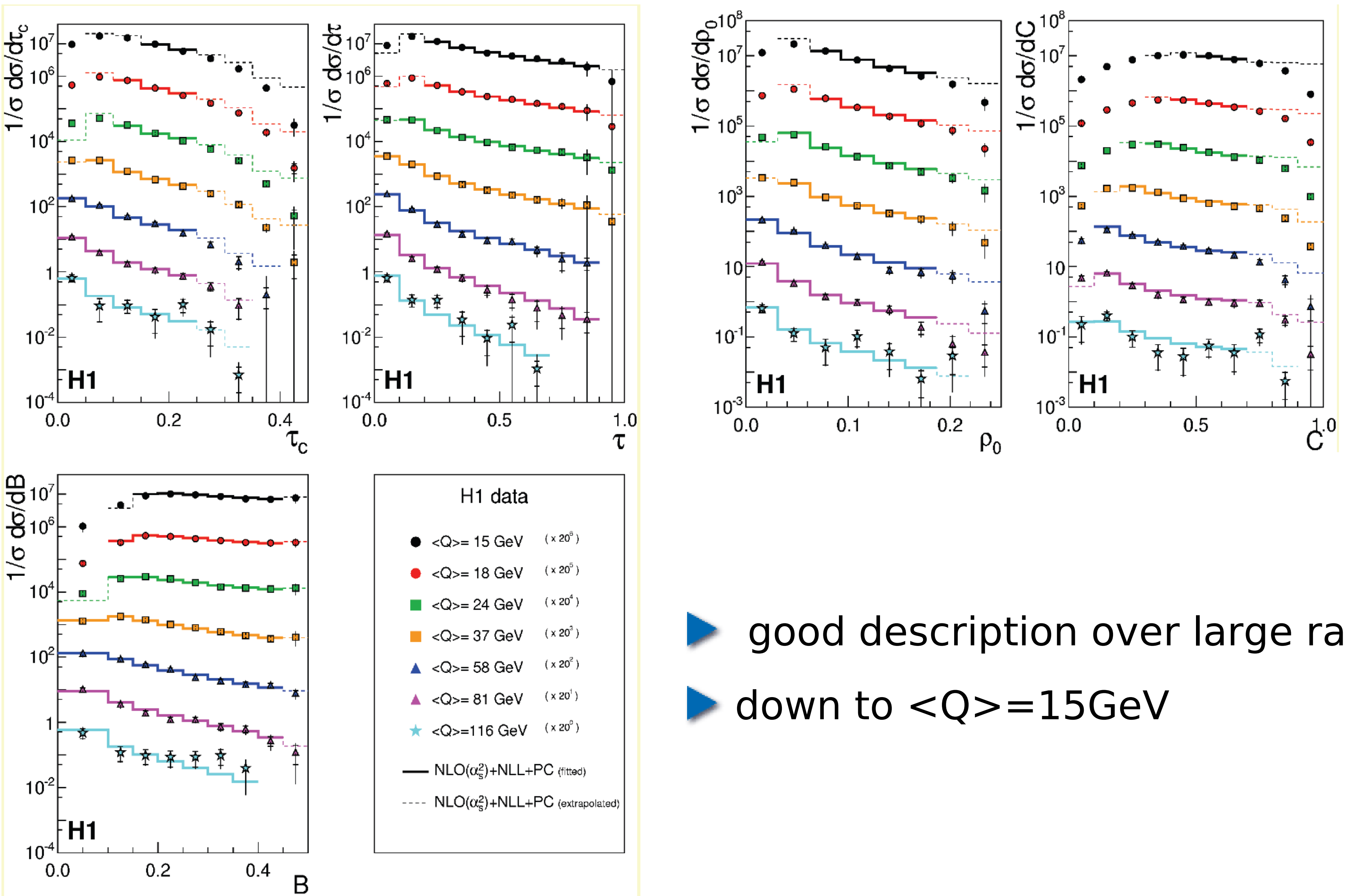


- pQCD: DISPATCH/DISASTER++
- matched resummation: DISRESUM



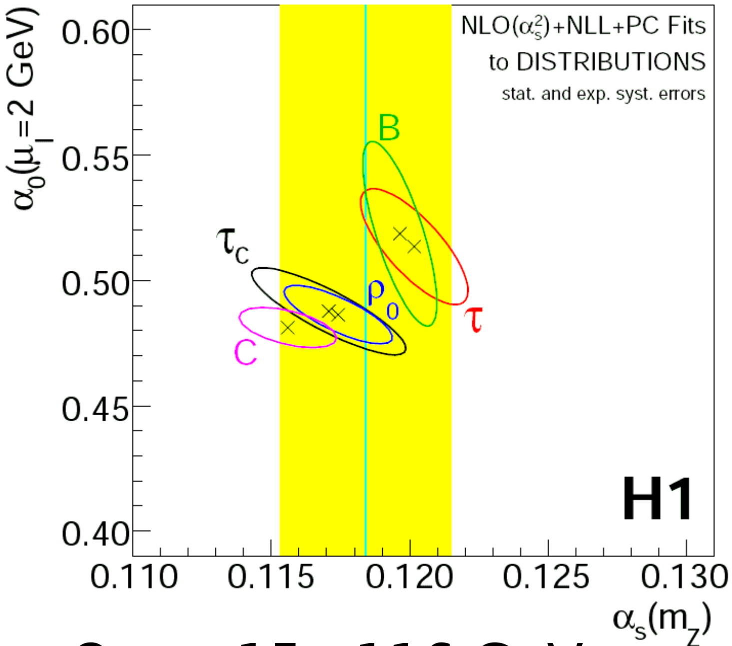
- + Dokshitzer,Webber power corrections: as implemented in DISRESUM

Distributions

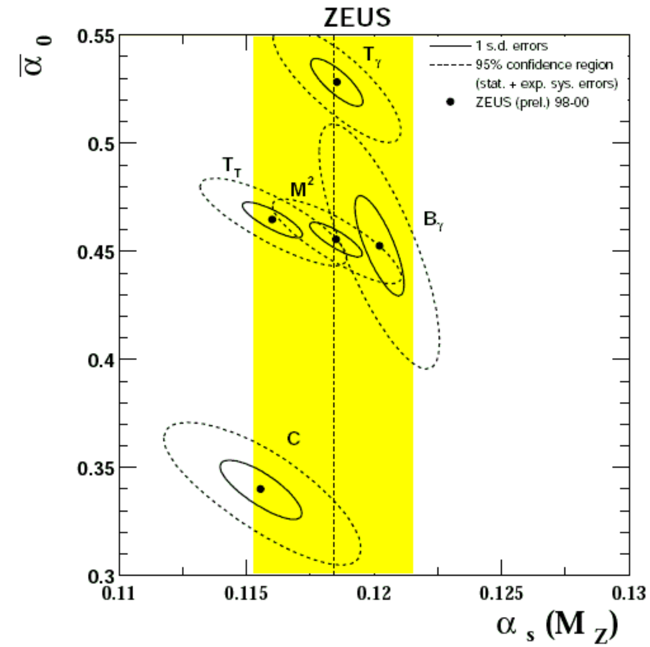


- good description over large range!
- down to <Q>=15GeV

Fits to Distributions

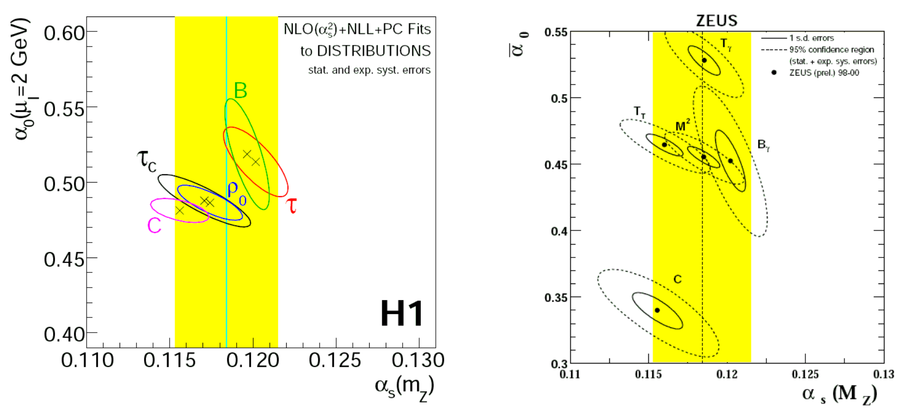


- $<Q>$ = 15...116 GeV
- χ^2/dof: 0.5...1.4, α_0 around 0.5
  α_s compatible with world mean
- grouping: γ-axis / others
- τ and C: ~2.5σ apart
- Average: $$\alpha_s(m_Z) = 0.1198 \pm 0.0013\,(\text{exp})\,^{+0.0056}_{-0.0043}\,(\text{theo})$$ $$\alpha_0 = 0.476 \pm 0.008\,(\text{exp})\,^{+0.018}_{-0.059}\,(\text{theo})$$



- $<Q>$ = 21...113 GeV
- χ^2/dof: T_γ and B_γ ~1, others 5
- C-parameter: low value of α_0, else around 0.5

Comparison of H1/ZEUS Results



DISAGREE

- ZEUS:
  - C-par: α_0 low
  - overall α_0 lower, except T_γ
  - χ^2/dof large for T_t,ρ_0,C

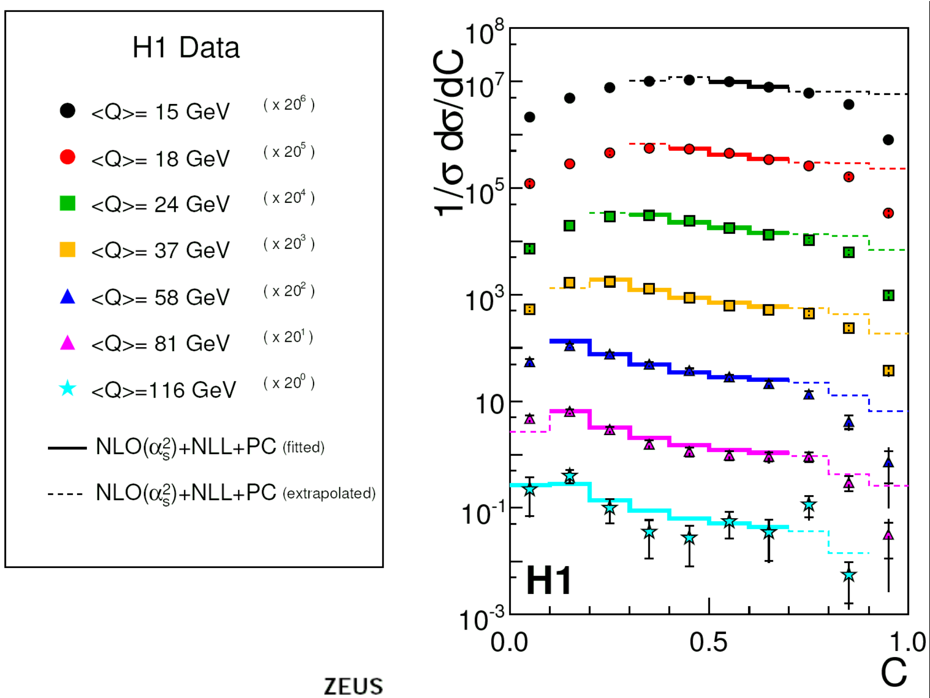
AGREE

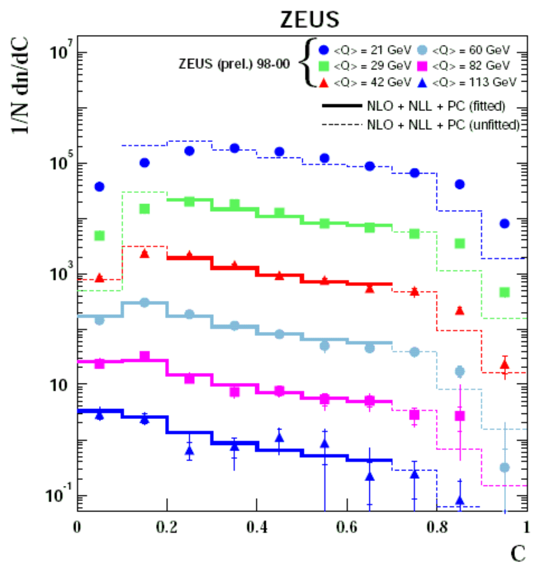
- α_s compatible with world mean
- α_s shape-by-shape
- neg. correlation between (α_s,α_0)
- C prefers lowest (α_s,α_0) values
- χ^2/dof best for γ-axis variables

DIFFERENCES

- correlations: H1 uses Bayes unfolding, syst. correlations
- matching scheme:
  H1: mod logR, ZEUS: mod M^2
- bins used for fitting different

Fit Ranges





- H1: more bins at low Q
- ZEUS: more bins at low F
- variation of fitted bins and matching schemes included in H1 theory uncertainty
- γ–axis thrust „τ
  H1: α_0=0.51±0.03+0.01-0.02
  ZEUS: α_0=0.53±0.01
- γ–axis broadening „B"
  H1: α_0=0.52±0.04+0.03-0.01
  ZEUS: α_0=0.45±0.02

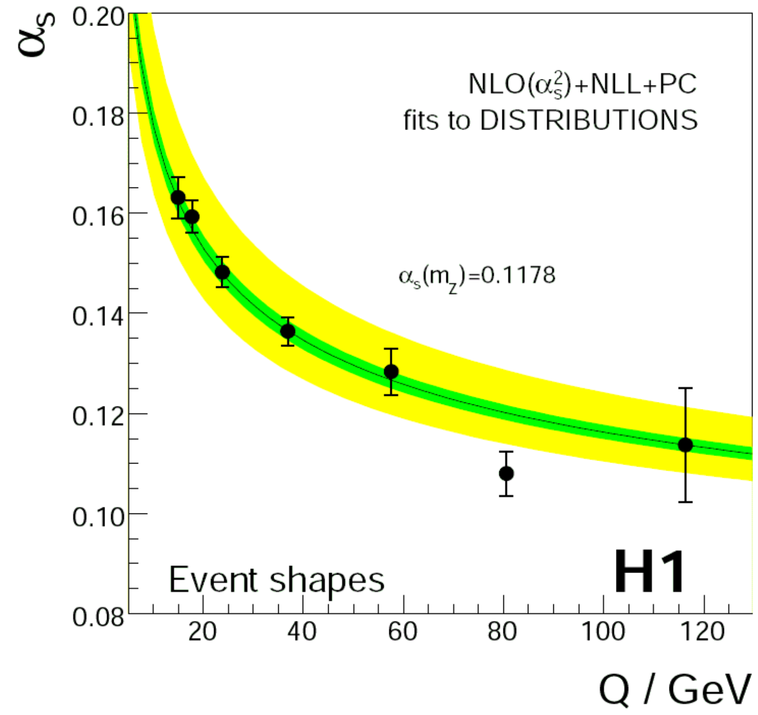
uncertainty: only matching, pdf and bins

H1 Distributions

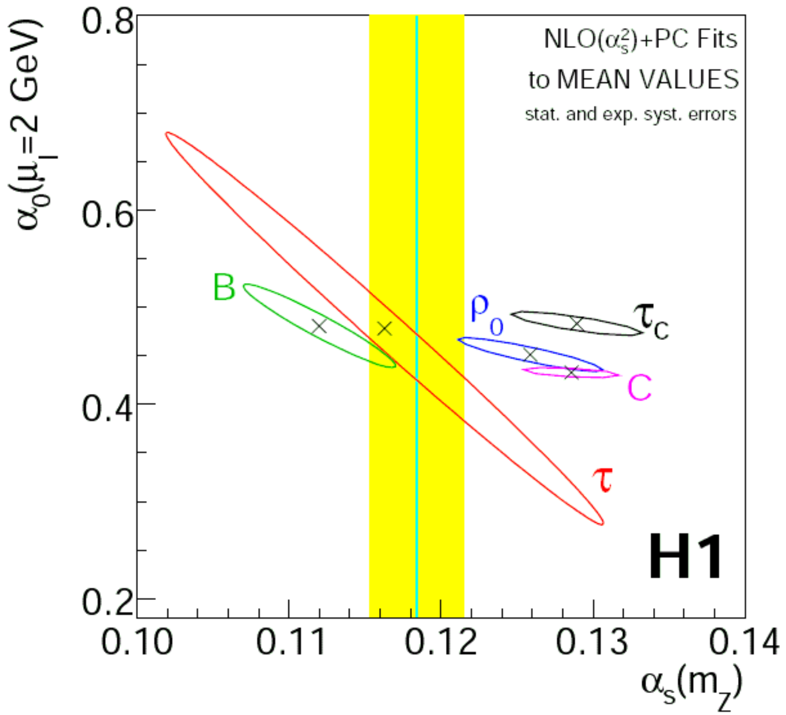
- now: assume PC valid
- fit $\alpha_s(Q)$ with shape specific α_0
- observe running for all shapes
- combine, estimate correlations between variables
- result:

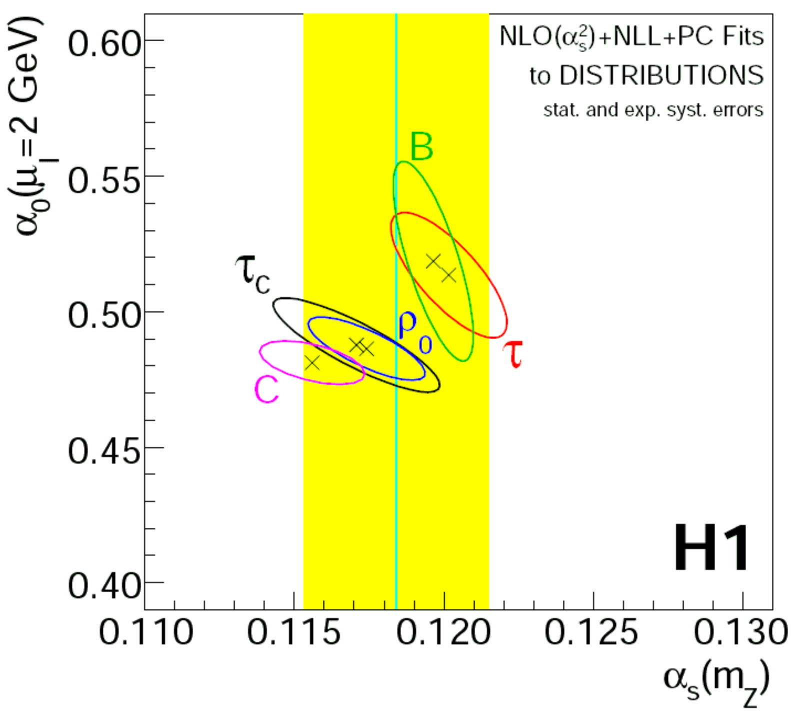
$$\alpha_s(m_Z) \quad = \quad 0.1178 \pm 0.0015\ (\text{exp})\ ^{+0.0081}_{-0.0061}\ (\text{theo})$$

- determination of $\alpha_s(Q)$ over large range of scale!
- sizable renormalisation scale uncertainty



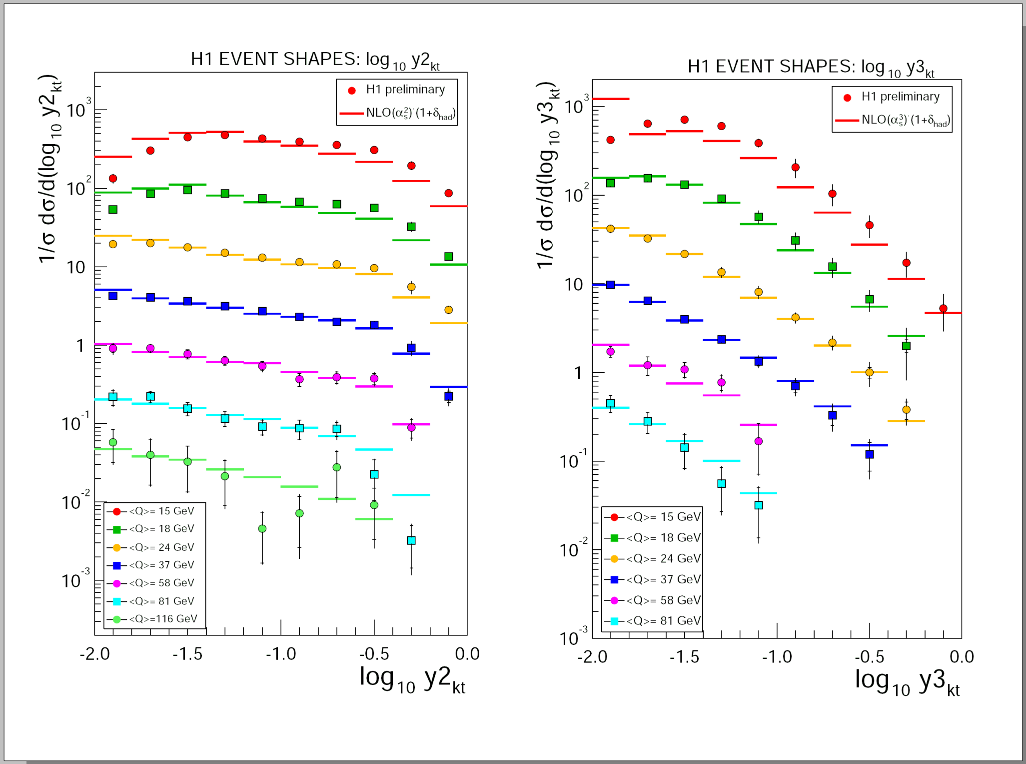
Means vs Distributions





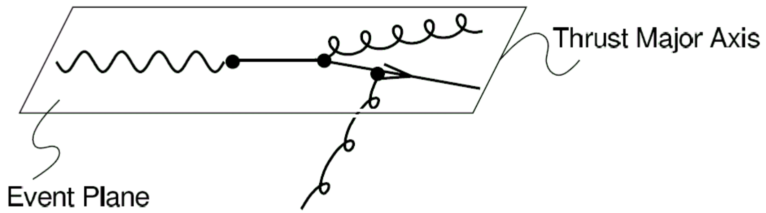
- Universality of α_0 : already good...
- ... improvements possible?

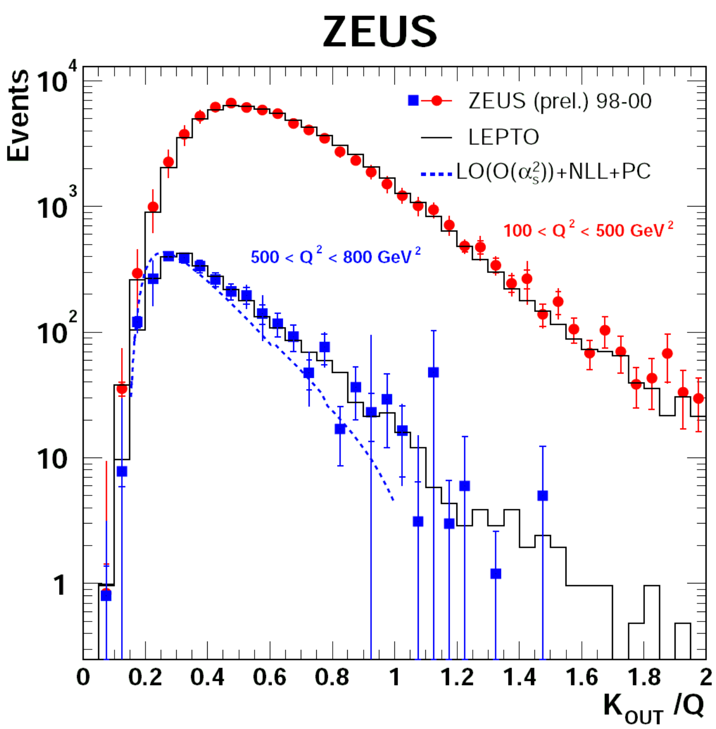
Jet rates Distributions



- distributions of jet rates
- H1 preliminary data
- power correction not known
- high Q -> hadronisation small
- fit of NLO with had. corr. from JETSET failed
- resummation needed?
- application for automated resummation (CAESAR)?

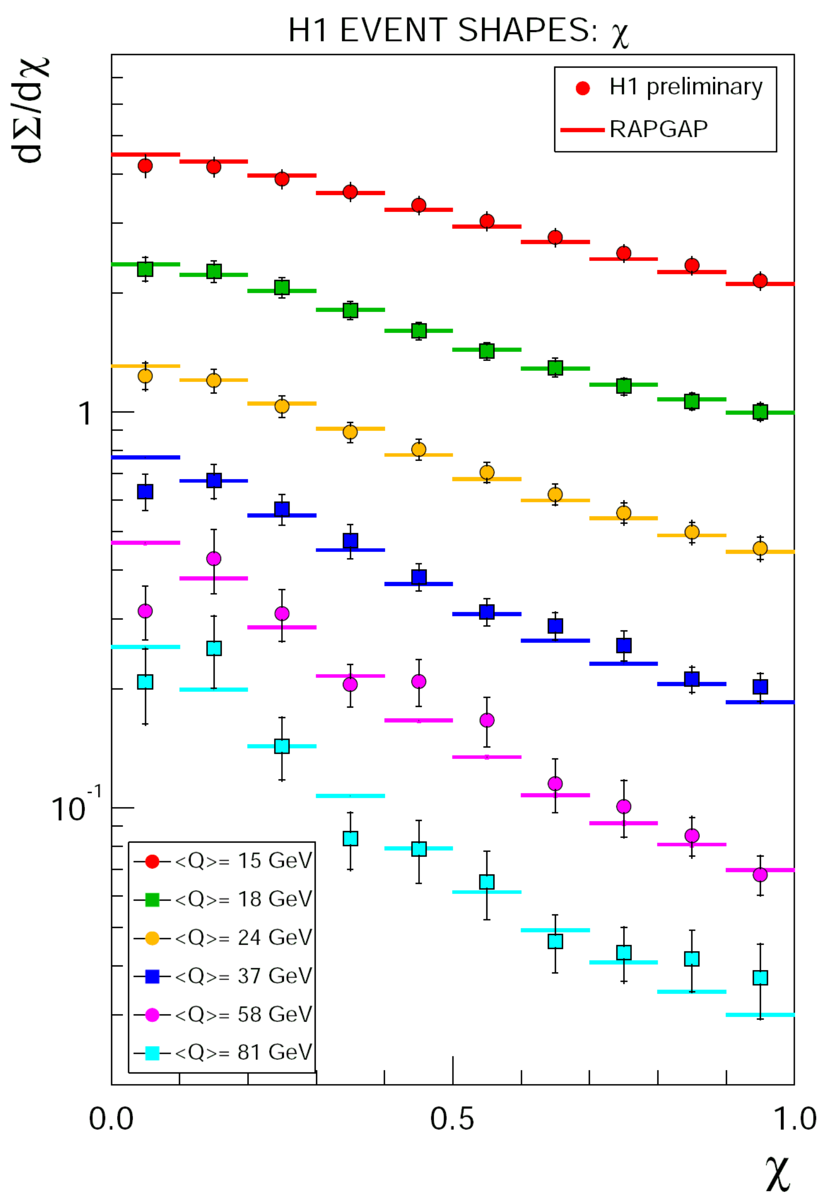
3-jet Distributions





- K_{out}: momentum out of event plane
- sensitive to large angle emissions, in between hard jets
- extend from current hemisphere ($\eta<0$) to $\eta<3$
- not so inclusive as 2-jet variables: require $0.1<y_2<2.5$
- rather well description by LO+NLL+PC at higher Q, but some shift
- also prel. H1 data available Q: 15...81 GeV

3-jet Distributions



- azimuthal correlation in the event plane: χ
- same requirements for η and y_2 as for K_{out}
- for χ and K_{out} need pQCD at α_s^3
- NLOJET++ with matched resummation?

Summary and Conclusion

STATUS

- mean values of 2-jet event shapes
  - consistent between H1 and ZEUS
  - universality of α_0, spread in α_s
- distributions of 2-jet event shapes
  - recent H1 analysis: consistent α_0 and α_s
  - ZEUS preliminary: larger spread in α_0
- distributions of 3-jet event shapes
  - preliminary data for K_{out} and χ available
  - up to now comparison to LO+NLL+PC

(personal) WISHLIST

- confirmation for distributions by ZEUS
- resummed calculation matched with pQCD at α_s^3 for 3-jet distributions
- power corrections for k_t jet rate

Backup

# of Q bin	1	2	3	4	5	6	7
Q Interval/GeV	[14,16]	[16,20]	[20,30]	[30,50]	[50,70]	[70,100]	[100,200]
$\langle Q \rangle$/GeV	14.9	17.7	23.8	36.9	57.6	80.6	115.6
$\langle x \rangle$	0.00841	0.0118	0.0209	0.0491	0.116	0.199	0.323

strong coupling constant $\alpha_s(m_Z)$					
event shape variable	τ_c	τ	B	ρ_0	C
central value	0.1171	0.1202	0.1196	0.1174	0.1156
uncertainties:					
total	$^{+0.0068}_{-0.0062}$	$^{+0.0072}_{-0.0058}$	$^{+0.0072}_{-0.0064}$	$^{+0.0070}_{-0.0056}$	$^{+0.0073}_{-0.0054}$
total experimental	± 0.0035	± 0.0021	± 0.0014	± 0.0021	± 0.0021
statistical experimental	± 0.0014	± 0.0006	± 0.0004	± 0.0010	± 0.0009
systematic experimental	± 0.0033	± 0.0020	± 0.0013	± 0.0019	± 0.0019
total theoretical	$^{+0.0058}_{-0.0051}$	$^{+0.0068}_{-0.0054}$	$^{+0.0071}_{-0.0063}$	$^{+0.0067}_{-0.0052}$	$^{+0.0069}_{-0.0049}$
μ_r dependence	$^{+0.0054}_{-0.0048}$	$^{+0.0058}_{-0.0043}$	$^{+0.0056}_{-0.0044}$	$^{+0.0064}_{-0.0050}$	$^{+0.0069}_{-0.0048}$
μ_I dependence	$^{+0.0002}_{-0.0002}$	$<10^{-4}$	$<10^{-4}$	$^{+0.0002}_{-0.0002}$	$<10^{-4}$
fit interval	$^{+0.0015}_{-0.0018}$	$^{+0.0007}_{-0.0022}$	$^{+0.0001}_{-0.0009}$	$^{+0.0010}_{+0.0007}$	$^{+0.0003}_{-0.0004}$
parton density functions	$^{+0.0002}_{-0.0001}$	$^{+0.0003}_{-0.0010}$	$^{+0.0006}_{-0.0007}$	$^{+0.0001}_{-0.0002}$	$^{+0.0002}_{-0.0001}$
matching scheme	$^{+0.0015}_{+0.0005}$	$^{+0.0036}_{+0.0022}$	$^{+0.0043}_{+0.0043}$	$^{+0.0018}_{+0.0009}$	$^{-0.0005}_{-0.0009}$

non perturbative coupling $\alpha_0(\mu_I = 2\,\mathrm{GeV})$					
event shape variable	τ_c	τ	B	ρ_0	C
central value	0.488	0.513	0.519	0.486	0.481
uncertainties:					
total	$^{+0.037}_{-0.035}$	$^{+0.034}_{-0.039}$	$^{+0.059}_{-0.049}$	$^{+0.023}_{-0.035}$	$^{+0.028}_{-0.042}$
total experimental	± 0.021	± 0.025	± 0.039	± 0.014	± 0.008
statistical experimental	± 0.009	± 0.009	± 0.006	± 0.006	± 0.005
systematic experimental	± 0.019	± 0.023	± 0.038	± 0.013	± 0.007
total theoretical	$^{+0.030}_{-0.027}$	$^{+0.022}_{-0.029}$	$^{+0.044}_{-0.029}$	$^{+0.019}_{-0.032}$	$^{+0.026}_{-0.041}$
μ_r dependence	$^{+0.020}_{-0.026}$	$^{+0.018}_{-0.027}$	$^{+0.030}_{-0.028}$	$^{+0.017}_{-0.027}$	$^{+0.022}_{-0.038}$
fit interval	$^{+0.022}_{-0.007}$	$^{+0.008}_{-0.005}$	$^{+0.030}_{+0.006}$	$^{-0.003}_{-0.016}$	$^{+0.006}_{-0.003}$
parton density functions	$^{+0.001}_{-0.001}$	$^{+0.006}_{+0.004}$	$^{+0.011}_{+0.003}$	$^{+0.001}_{-0.001}$	$^{+0.001}_{-0.002}$
matching scheme	$^{-0.005}_{-0.012}$	$^{-0.009}_{-0.023}$	$^{+0.006}_{-0.010}$	$^{-0.006}_{-0.009}$	$^{-0.014}_{-0.014}$

correlation coefficient α_s,α_0	−0.85	−0.76	−0.75	−0.78	−0.51
χ^2 / d.o.f. (experimental errors)	1.13	0.51	0.81	1.40	1.20