DIS 99

Event Shapes and Power Corrections in ep DIS

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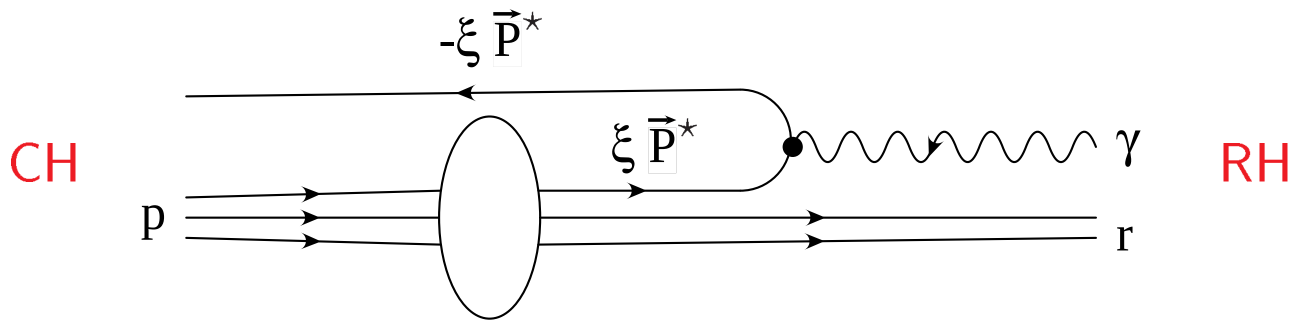
Outline

- Definition of the Event Shape Variables
- Phase Space
- Unfolded Distributions vs. NLO
- $1/Q^p$-Fits
- Fits à la Dokshitzer, Webber et al.
- Systematic Uncertainties
- Summary

Definition of the Event Shape Variables



QPM-type ep collision in the Breit frame.⋆

- Event shapes employing the boson axis $\vec{q}^{\,\star}$ as event axis $\vec{n}$:

1−thrust:

$$\tau := 1 - \frac{\sum_{i \in \mathrm{CH}} |\vec{p}_i^{\,\star} \cdot \vec{n}|}{\sum_{i \in \mathrm{CH}} |\vec{p}_i^{\,\star}|} = 1 - \frac{\sum_{i \in \mathrm{CH}} |p_{li}^{\star}|}{P^{\star}}$$

jet broadening:

$$B := \frac{\sum_{i \in \mathrm{CH}} |\vec{p}_i^{\,\star} \times \vec{n}|}{2 \sum_{i \in \mathrm{CH}} |\vec{p}_i^{\,\star}|} = \frac{\sum_{i \in \mathrm{CH}} |p_{ti}^{\star}|}{2 P^{\star}}$$

- Event shapes without reference to the boson axis as event axis:

1−thrust_C:

$$\tau_C := 1 - \max_{\vec{n},\vec{n}^2=1} \frac{\sum_{i\in\mathrm{CH}} |\vec{p_i}^\star \cdot \vec{n}|}{\sum_{i\in\mathrm{CH}} |\vec{p_i}^\star|} = 1 - \frac{\sum_{i\in\mathrm{CH}} |\vec{p_i}^\star \cdot \vec{n}_T|}{P^\star}$$

jet mass:

$$\rho := \frac{\left(\sum_{i\in\mathrm{CH}} p_i^\star\right)^2}{4\left(\sum_{i\in\mathrm{CH}} E_i^\star\right)^2} = \frac{M^2}{4E^{\star 2}}$$

C parameter:

$$C := 3(\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1)$$

with $\lambda_i\,, i = 1, 2, 3$ being the eigen values of the momentum tensor

$$\Theta^\star_{jk} := \frac{\sum_{i\in\mathrm{CH}} \frac{p^\star_{j_i} p^\star_{k_i}}{|\vec{p_i^\star}|}}{\sum_{i\in\mathrm{CH}} |\vec{p_i^\star}|}$$

- Event shapes employing jet algorithms:

  Distance measures between objects, y_{ij}, and with respect to the remnant, y_{ir}, for the factorizable JADE algorithm

$$y_{ij} := \frac{2E_i^\star E_j^\star(1-\cos\theta_{ij}^\star)}{Q^2}$$

$$y_{ir} := \frac{2E_i^\star x E_p^\star(1-\cos\theta_i^\star)}{Q^2}$$

  and the k_t algorithm

$$y_{ij} := \frac{2\min({E_i^\star}^2, {E_j^\star}^2)(1-\cos\theta_{ij}^\star)}{Q^2}$$

$$y_{ir} := \frac{2{E_i^\star}^2(1-\cos\theta_i^\star)}{Q^2}.$$

  y_{fJ} and y_{k_t} denote the transition values $(2+1) \rightarrow (1{+}1)$ jets.

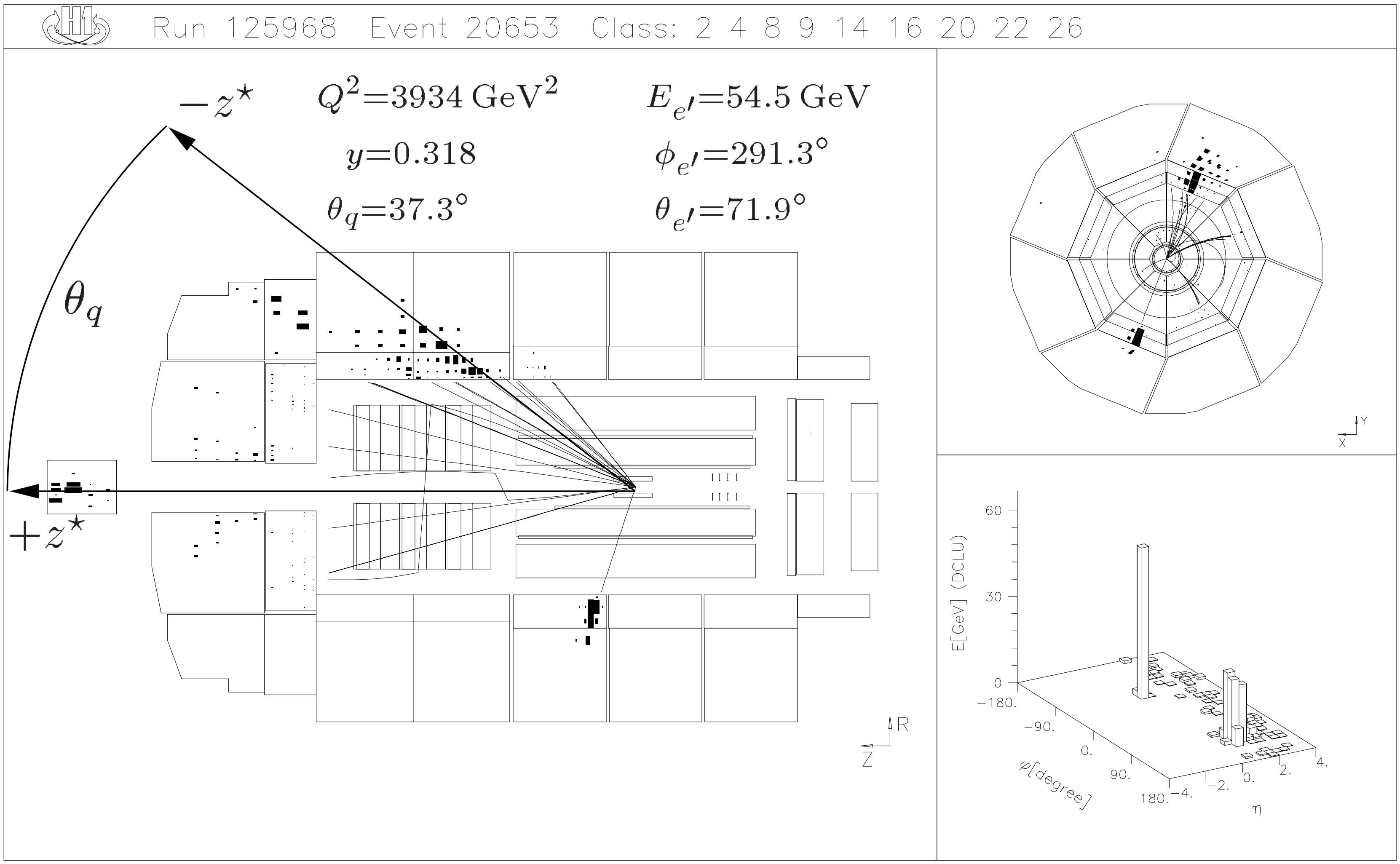
Phase Space

low Q^2	high Q^2
$\mathcal{L}_{\rm int} = 3.2\,{\rm pb}^{-1}$	$\mathcal{L}_{\rm int} = 38.2\,{\rm pb}^{-1}$
$49 < Q^2/\,{\rm GeV}^2 < 10^2$	$196 < Q^2/\,{\rm GeV}^2 < 10^4$
$0.05 < y < 0.8$	
$E_{e'} > 14\,{\rm GeV}$	$E_{e'} > 11\,{\rm GeV}$
$157^\circ < \theta_{e'} < 173^\circ$	$30^\circ < \theta_{e'} < 150^\circ$
$20^\circ < \theta_q$	
$E^\star > Q/10$	

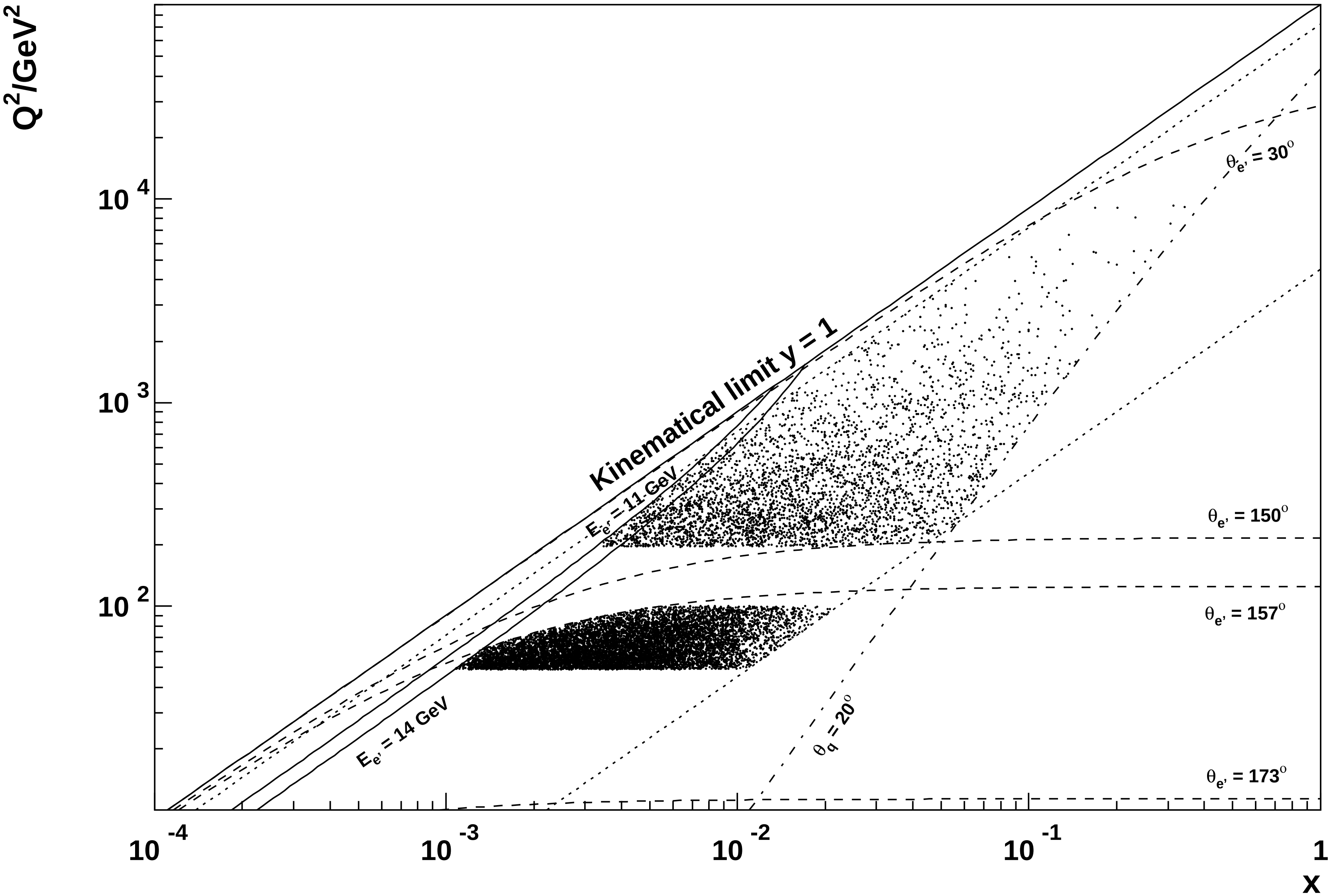
- Cut in polar angle θ_q of QPM quark direction $\Rightarrow$ ensure sufficient calorimeter resolution for Breit frame transformation.

- Minimal energy cut for the current hemisphere $E^\star > Q/10$ not applied to the y_2 variables.

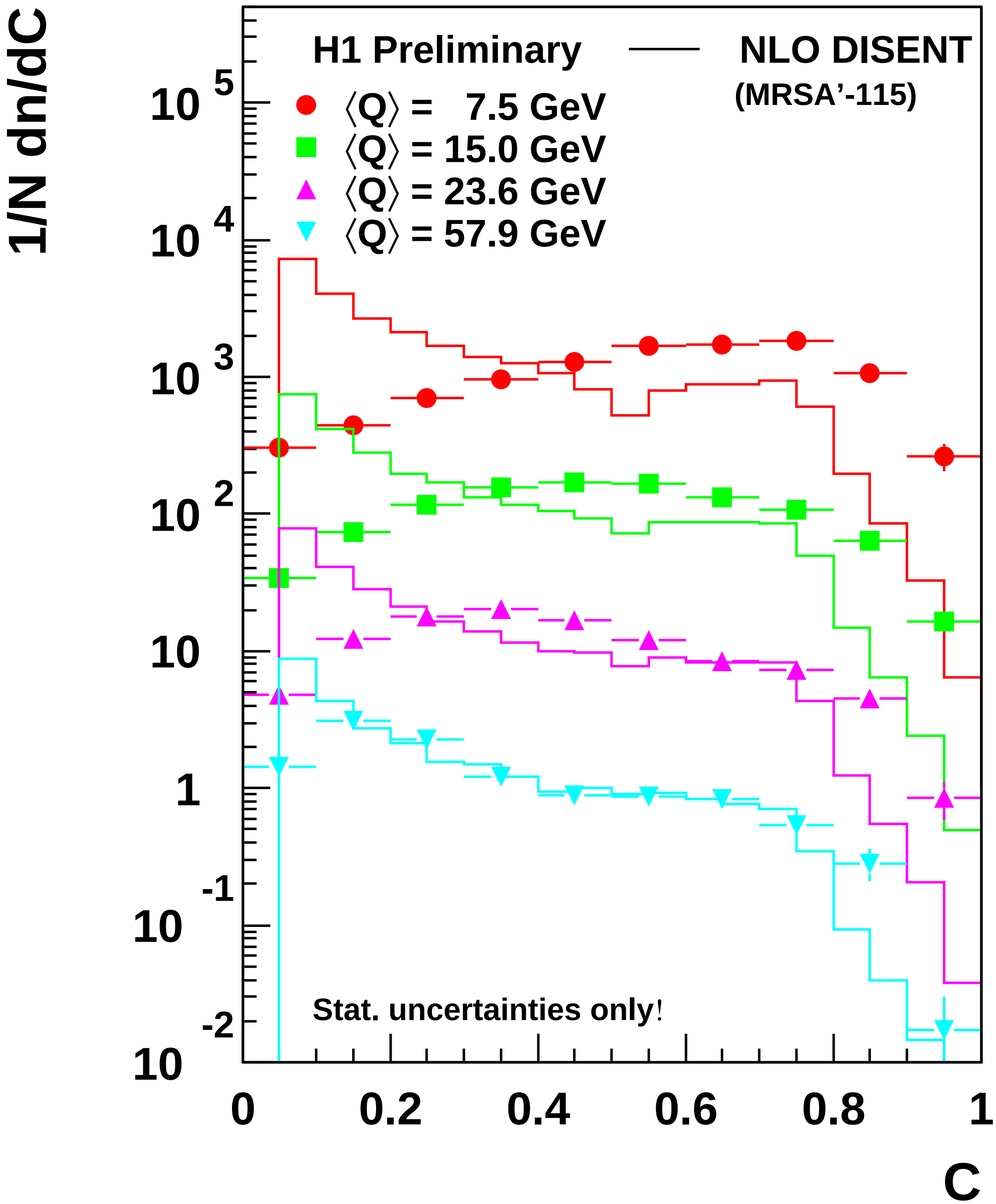
Neutral Current (1+1) Event



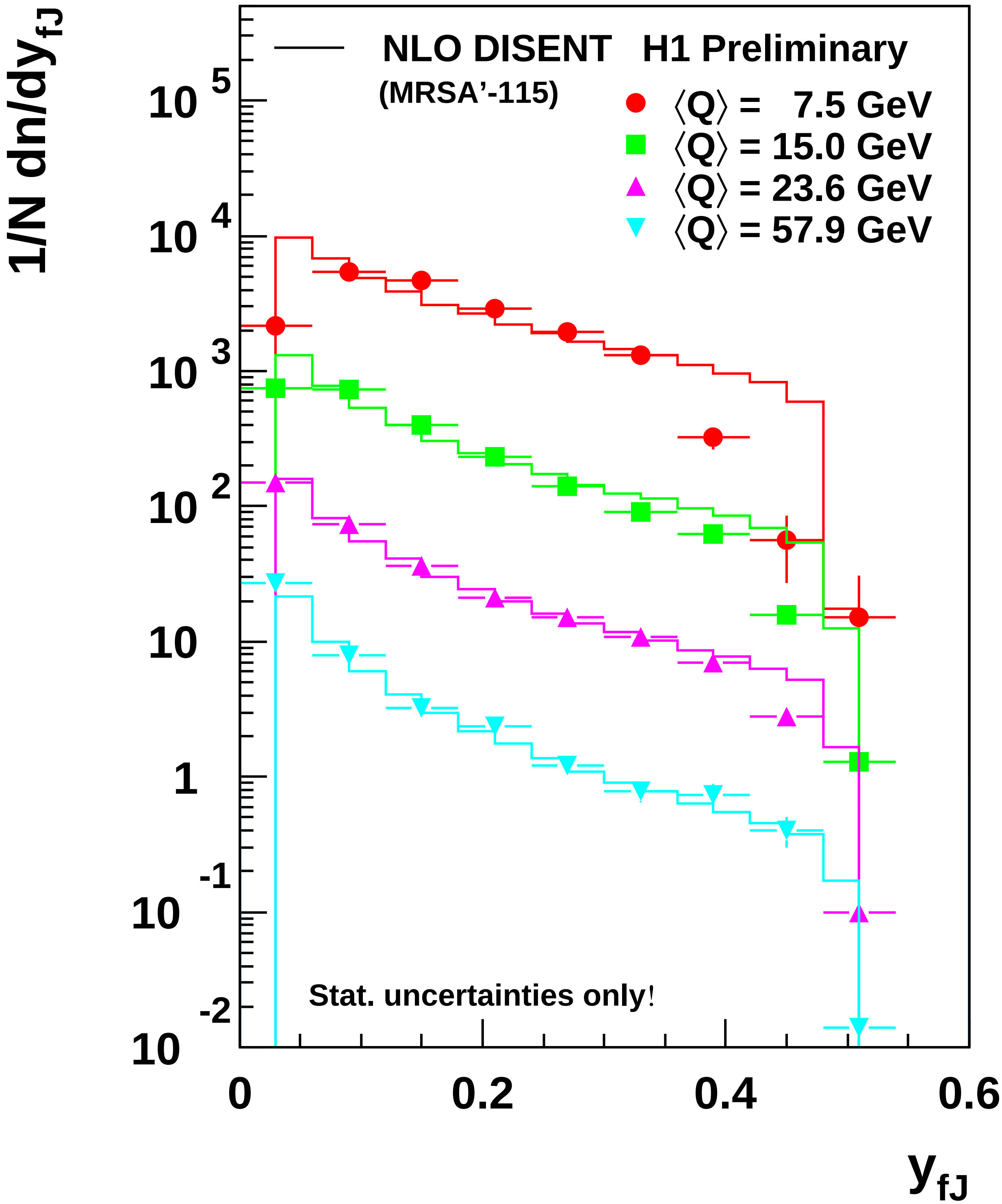
Kinematic Plane in (x, Q^2) for ep DIS



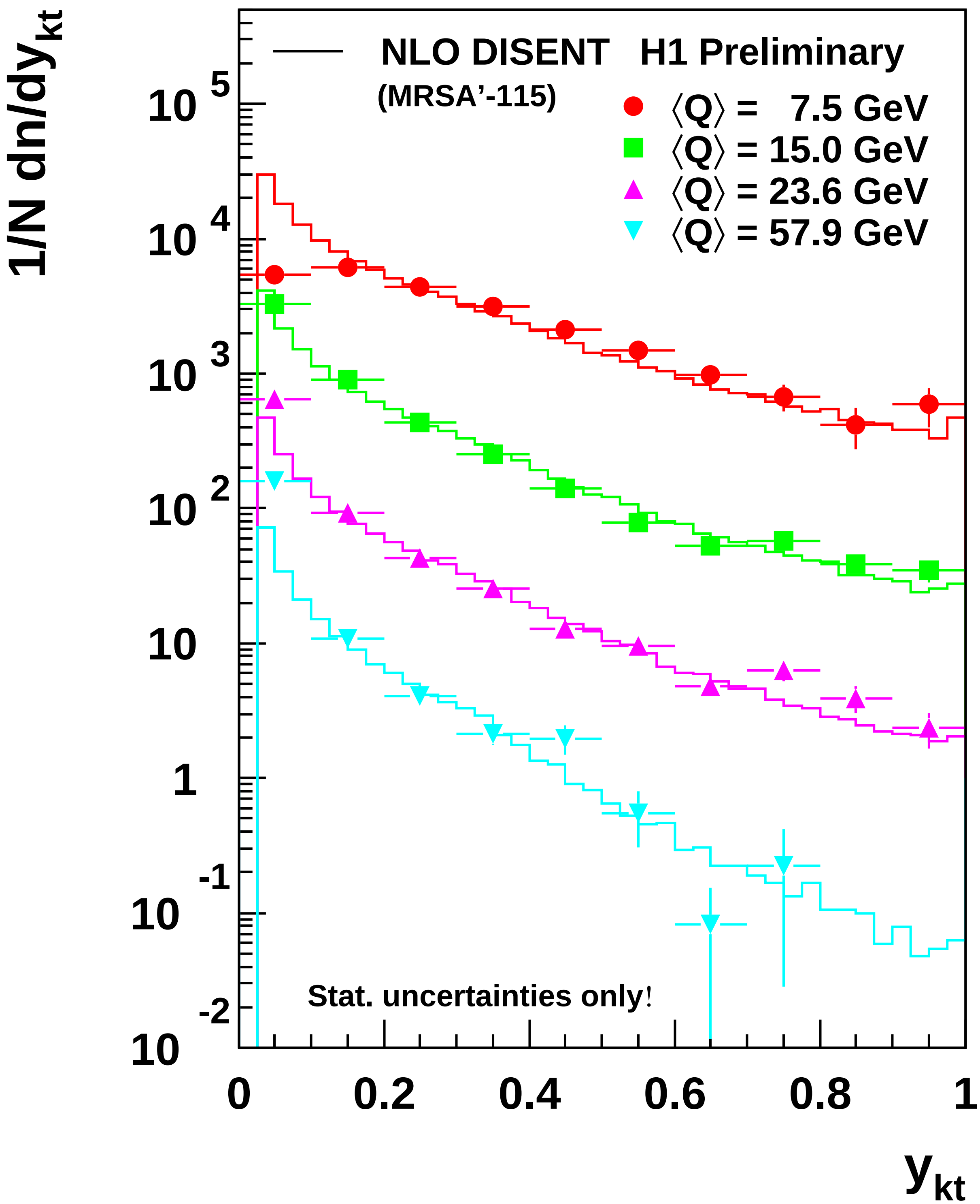
Unfolded Distributions vs. NLO



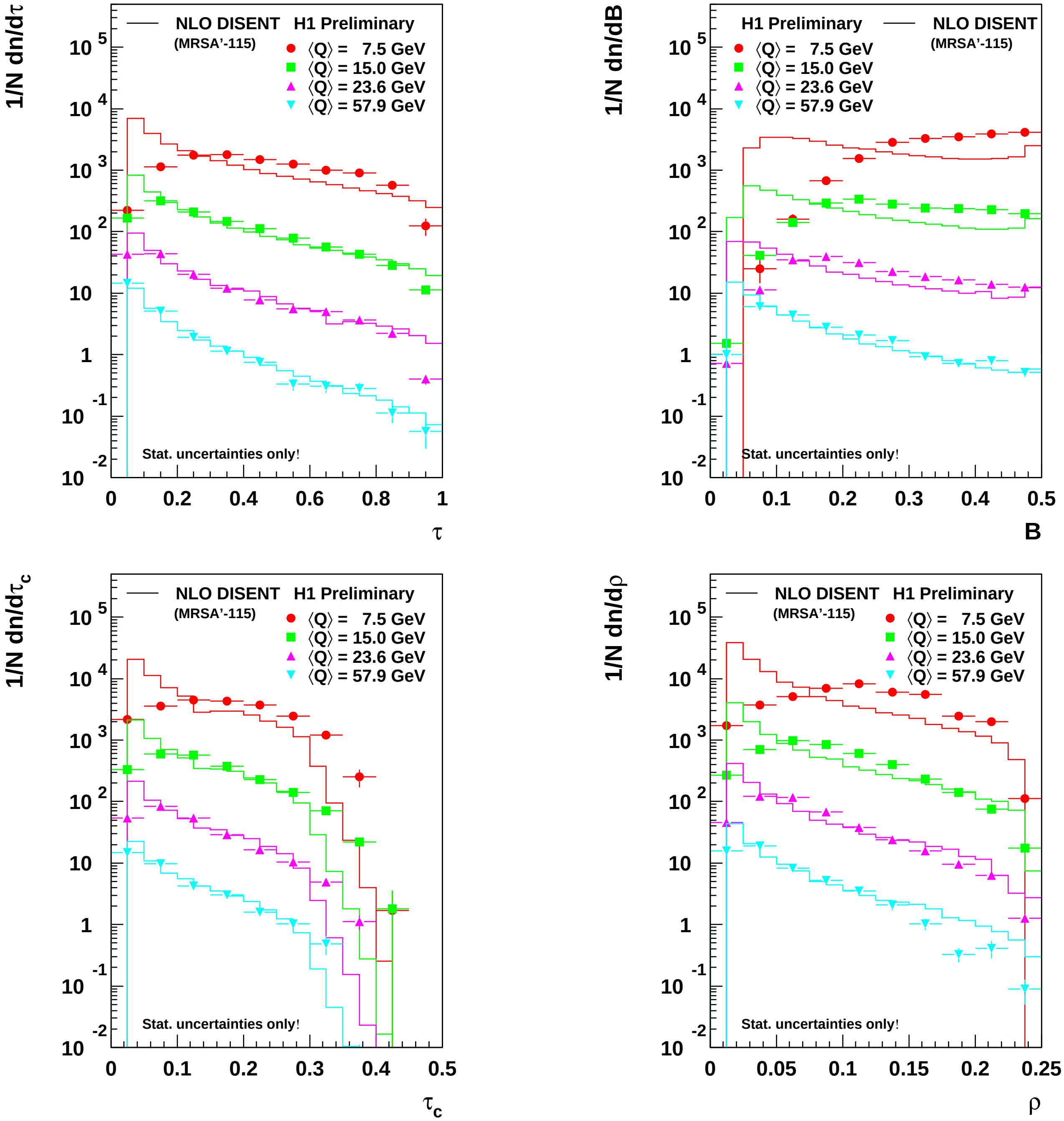
⇒ Large discrepancies diminishing with rising Q.



$\Rightarrow$ Better description of data already at low Q.

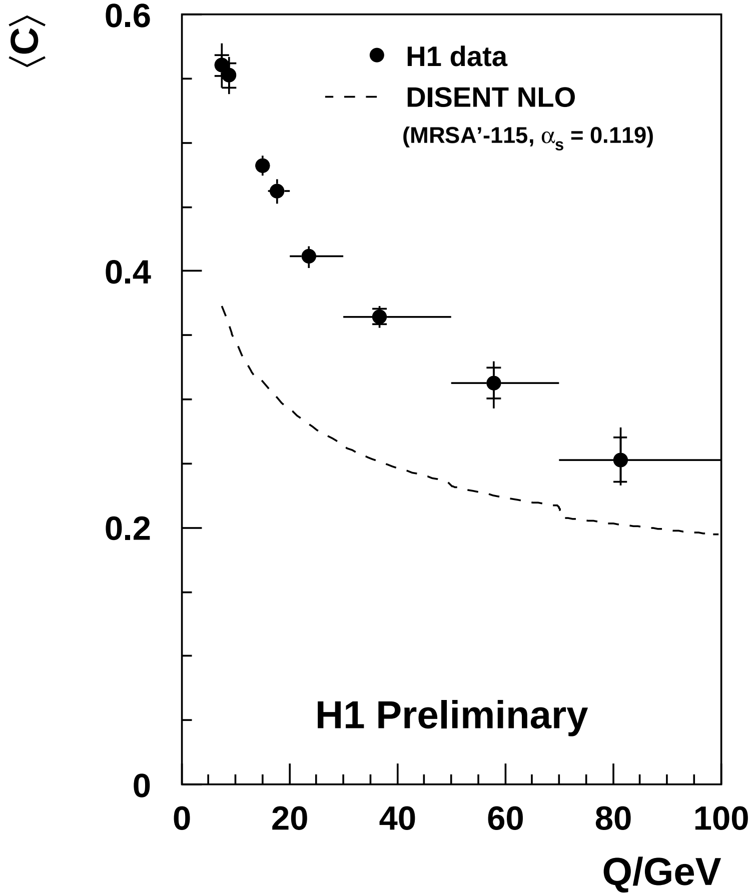


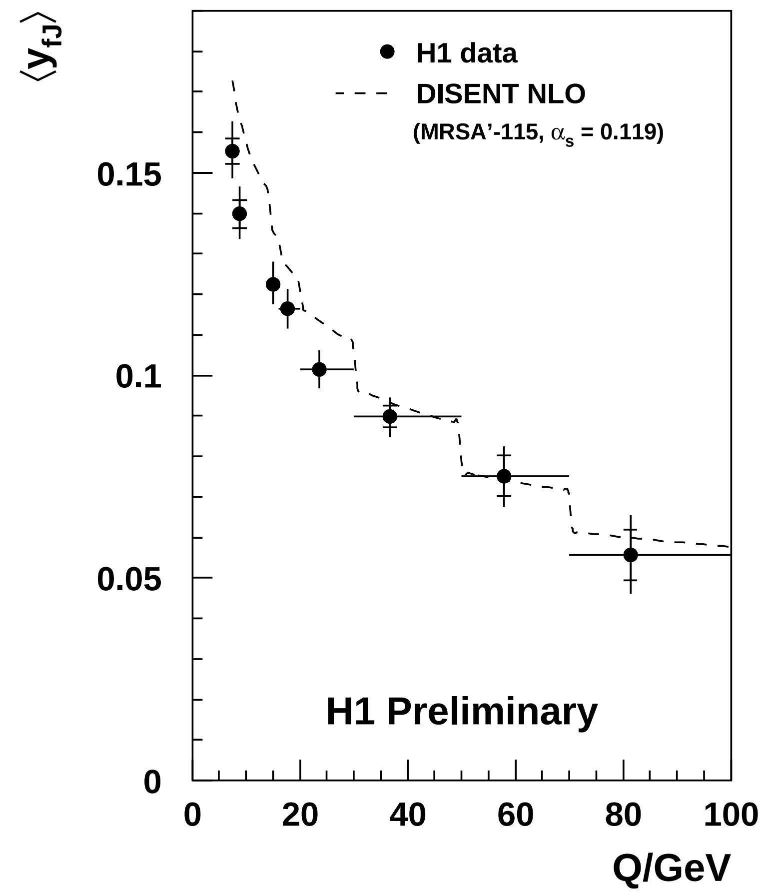
$\Rightarrow$ Better description of data for both y_2 variables.



Norm. diff. distributions of τ, B, τ_C and ρ.

Means of C and y_{fJ} vs. NLO





$\Rightarrow$ NLO prediction much smaller for C and slightly larger for y_{fJ}.

$1/Q^p$-Fits

⇒ Try ansatz

$$\langle F \rangle = \langle F \rangle^{\rm pert} + \langle F \rangle^{\rm pow}$$

where

$$\langle F \rangle^{\rm pert} = c_{1,F}\, \alpha_s(Q) + c_{2,F}\, \alpha_s^2(Q)\,.$$

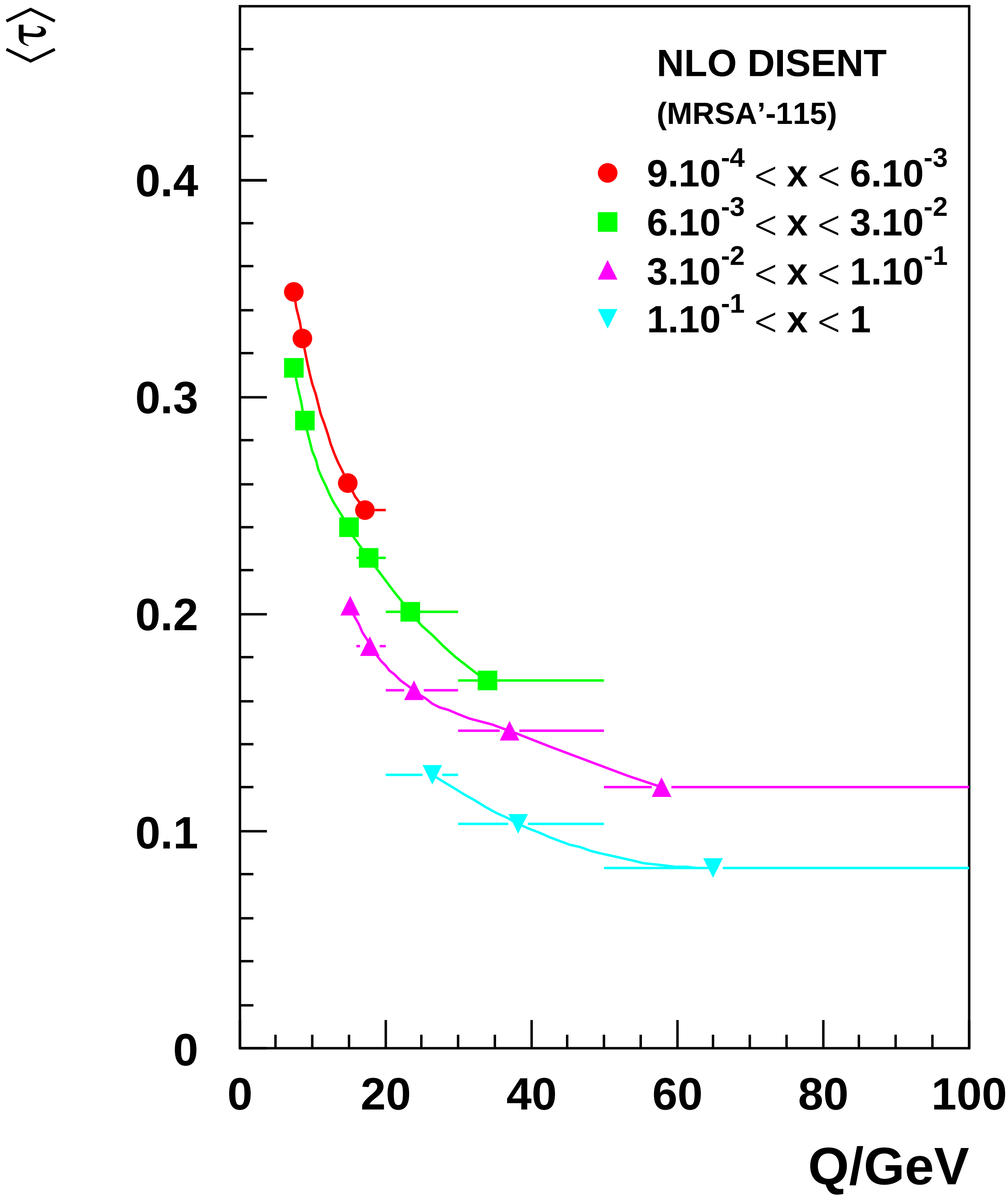
Note that $c_{1,F}$ and $c_{2,F}$ are x dependent!

Here, power corrections are parameterized as

$$\langle F \rangle^{\rm pow} = \frac{\lambda}{Q} \quad \text{or} \quad \langle F \rangle^{\rm pow} = \frac{\mu}{Q^2}\,.$$

⇒ expect $\lambda, \mu > 0$ except for y_2 where $\lambda, \mu \lesssim 0$!

x-Dependence of $\langle \tau \rangle$ in NLO



Two-parameter Fits acc. to simple $1/Q$ Power Corrections

H1 Preliminary				
$\langle F \rangle$	$\alpha_s(M_Z)$	$\lambda/$ GeV	χ^2_n	$\kappa/\%$
$\langle \tau \rangle$	0.132	-0.04	0.6	-99
$\langle B \rangle$	0.120	0.53	0.8	-92
$\langle \tau_C \rangle$	0.157	-0.15	1.3	-99
$\langle \rho \rangle$	0.165	-0.09	0.5	-99
$\langle C \rangle$	0.161	-1.39	2.0	-99
$\langle y_{fJ} \rangle$	0.114	-0.08	1.6	-97
$\langle y_{k_t} \rangle$	0.122	-0.45	1.6	-99

$\Rightarrow$ χ^2 per dof acceptable, but large correlations κ between $\alpha_s(M_Z)$ and λ.

$\Rightarrow$ Negative fit values of λ for τ, τ_C, ρ and C.

$\Rightarrow$ x-dependent λ?

Fits à la Dokshitzer, Webber et al.

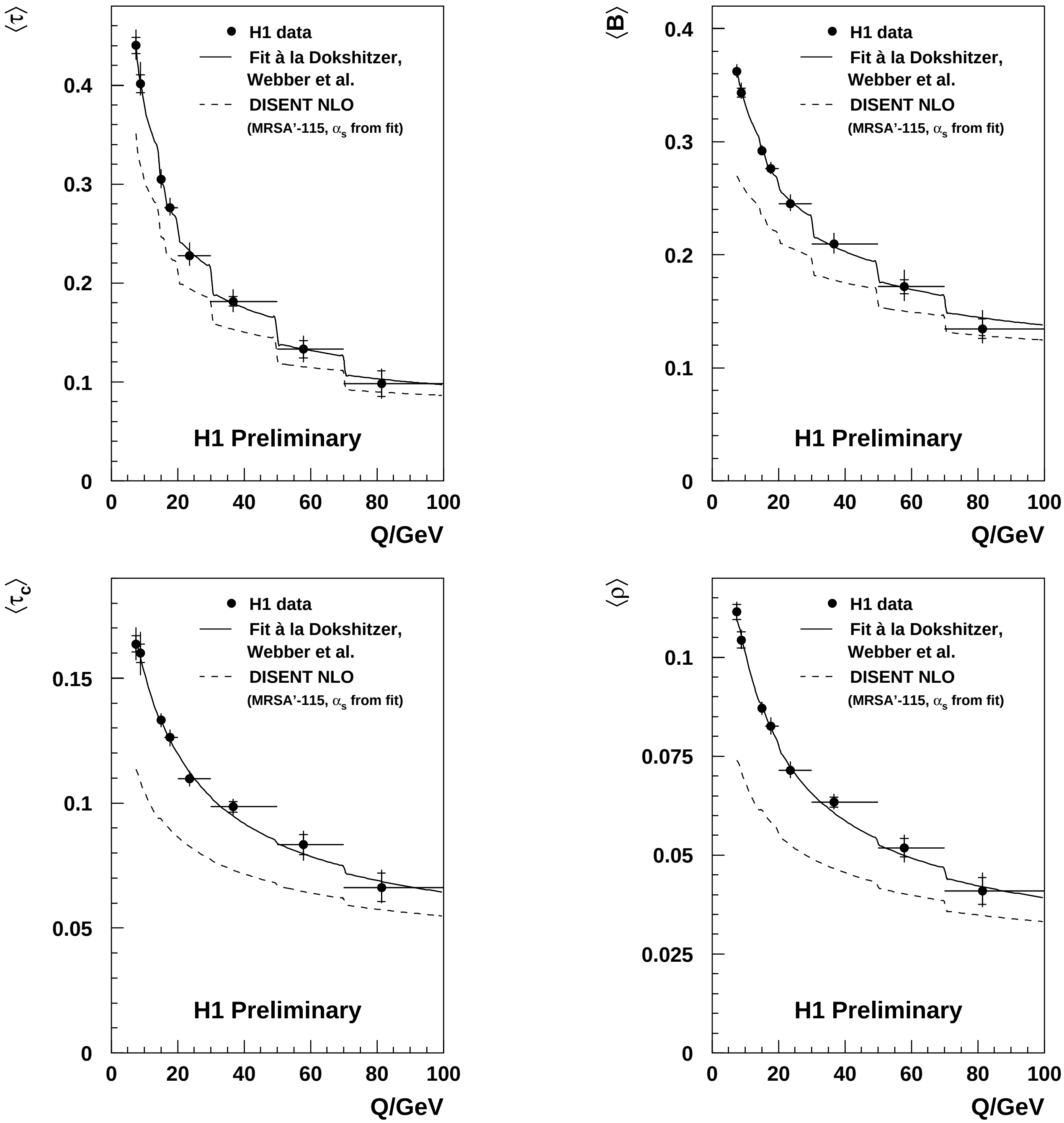
$$\langle F \rangle^{\mathrm{pow}} = a_F \frac{32}{3\pi^2} \frac{\mathcal{M}}{p} \left(\frac{\mu_I}{Q}\right)^p$$

$$\left[\overline{\alpha}_{p-1}(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\pi}\left(\ln\frac{Q}{\mu_I} + \frac{K}{\beta_0} + \frac{1}{p}\right)\alpha_s^2(Q)\right]$$

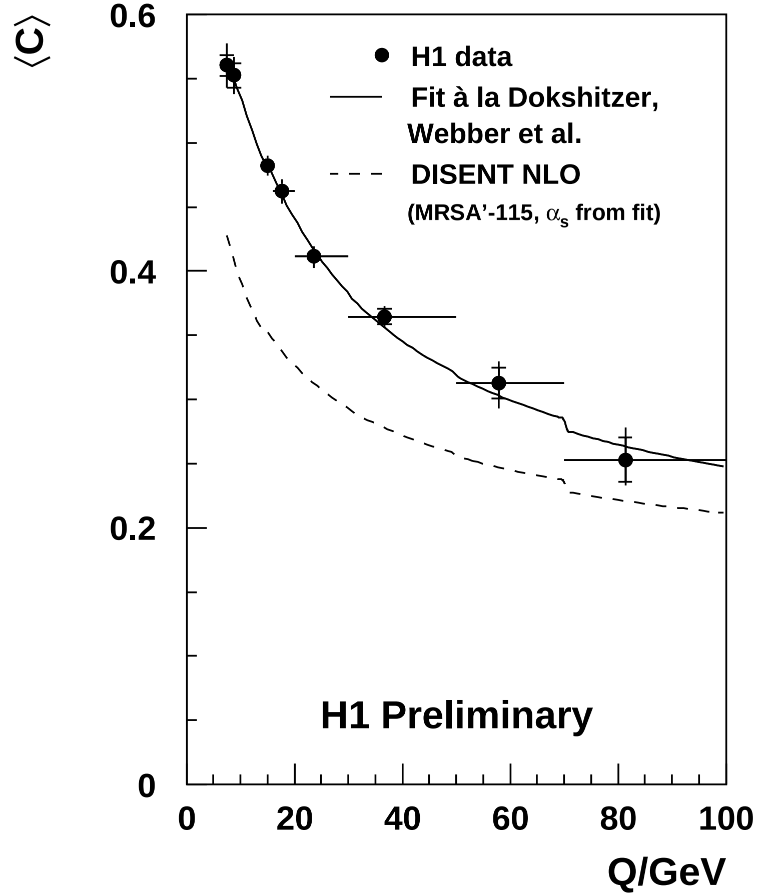
with

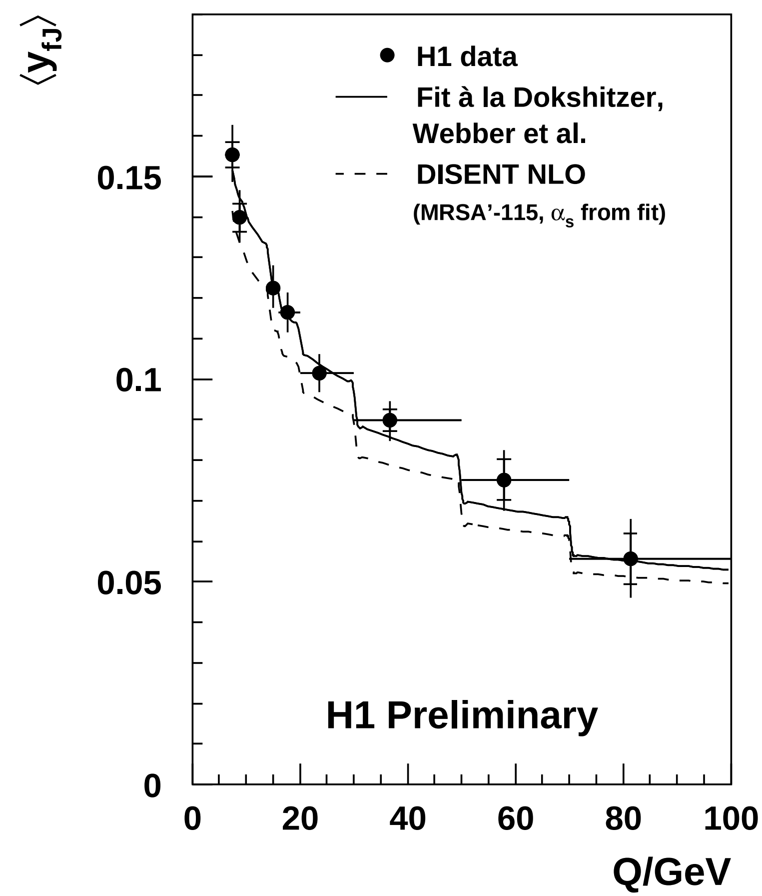
- a_F: calculable F dependent constant
  Note: Add. factor for $B \propto 1/\sqrt{\alpha_s} + \mathrm{const.}$!
- p: power $p = 1$ except for y_{k_t} where $p = 2$
- $2/\pi \cdot \mathcal{M} \approx 1.14$: 2-loop correction (Milan factor)
- μ_I: infrared matching scale, $\mu_I = 2\,\mathrm{GeV}$
- $\overline{\alpha}_{p-1}(\mu_I)$: universal (?) non-pert. parameter to fit

Fits to Means of τ, B, τ_C and ρ



Fits to Means of C and y_{fJ}





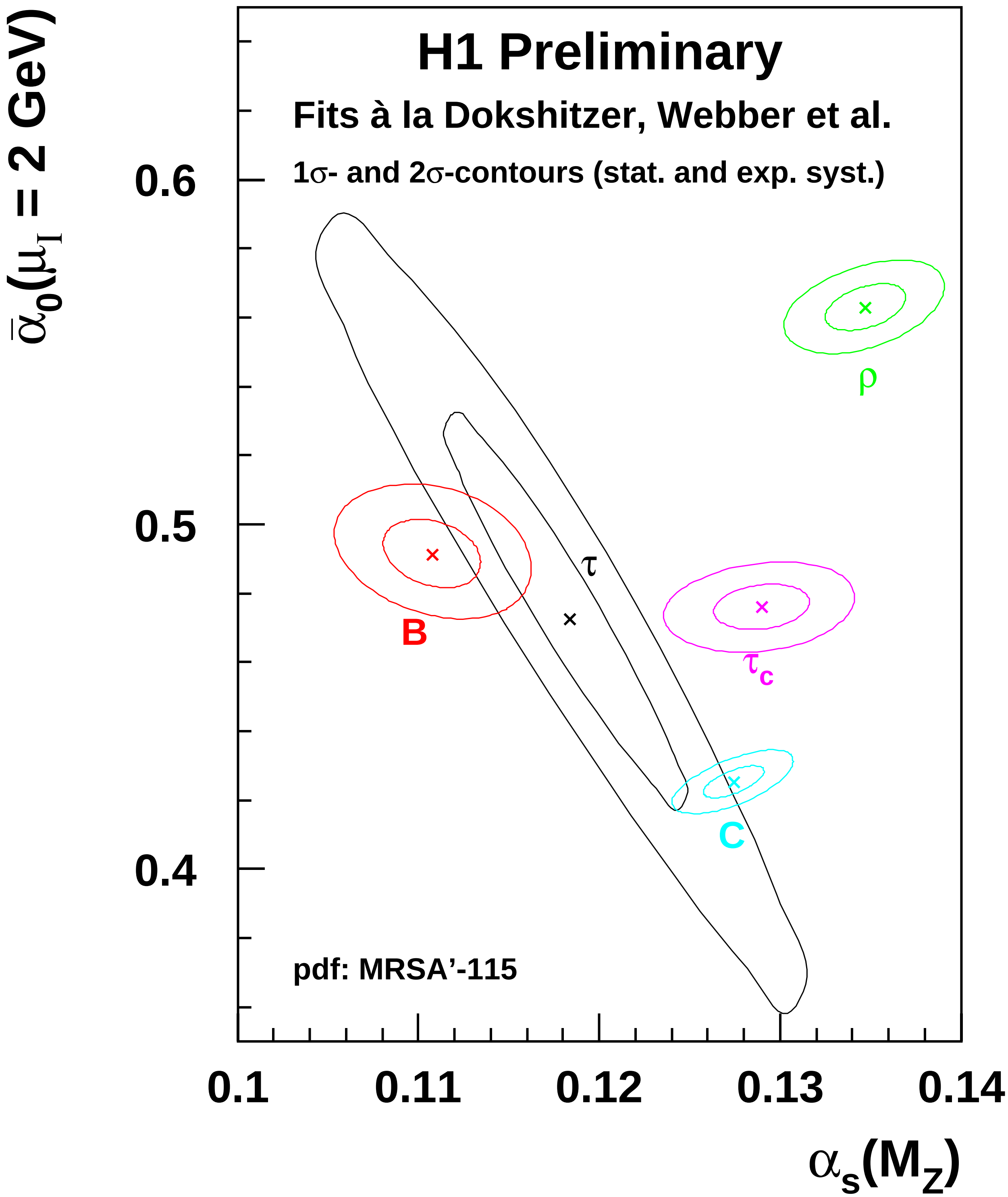
Two-parameter Fits acc. to Dokshitzer, Webber et al.

H1 Preliminary					
$\langle F\rangle$	a_F	$\overline{\alpha}_0(\mu_I = 2\,\mathrm{GeV})$	$\alpha_s(M_Z)$	χ^2/n	$\kappa/$…
$\langle\tau\rangle$	1	$0.480 \pm 0.028\ ^{+0.048}_{-0.062}$	$0.1174 \pm 0.0030\ ^{+0.0097}_{-0.0081}$	0.5	-9…
$\langle B\rangle$	$1/2 \cdot a'_B$	$0.491 \pm 0.005\ ^{+0.032}_{-0.036}$	$0.1106 \pm 0.0012\ ^{+0.0060}_{-0.0057}$	0.7	-5…
$\langle\tau_C\rangle$	1	$0.475 \pm 0.003\ ^{+0.044}_{-0.048}$	$0.1284 \pm 0.0014\ ^{+0.0100}_{-0.0092}$	1.3	$+1$…
$\langle\rho\rangle$	$1/2$	$0.561 \pm 0.004\ ^{+0.051}_{-0.058}$	$0.1347 \pm 0.0015\ ^{+0.0111}_{-0.0100}$	1.2	$+$…
$\langle C\rangle$	$3\pi/2$	$0.425 \pm 0.002\ ^{+0.033}_{-0.039}$	$0.1273 \pm 0.0009\ ^{+0.0104}_{-0.0093}$	0.9	$+6$…
$\langle y_{fJ}\rangle$	1	0.258 ± 0.004	0.104 ± 0.002	1.9	-6…

⇒ All $1/Q$ fits including B work reasonable.
⇒ Very low value of $\overline{\alpha}_0(\mu_I = 2\,\mathrm{GeV})$ for y_{fJ}.

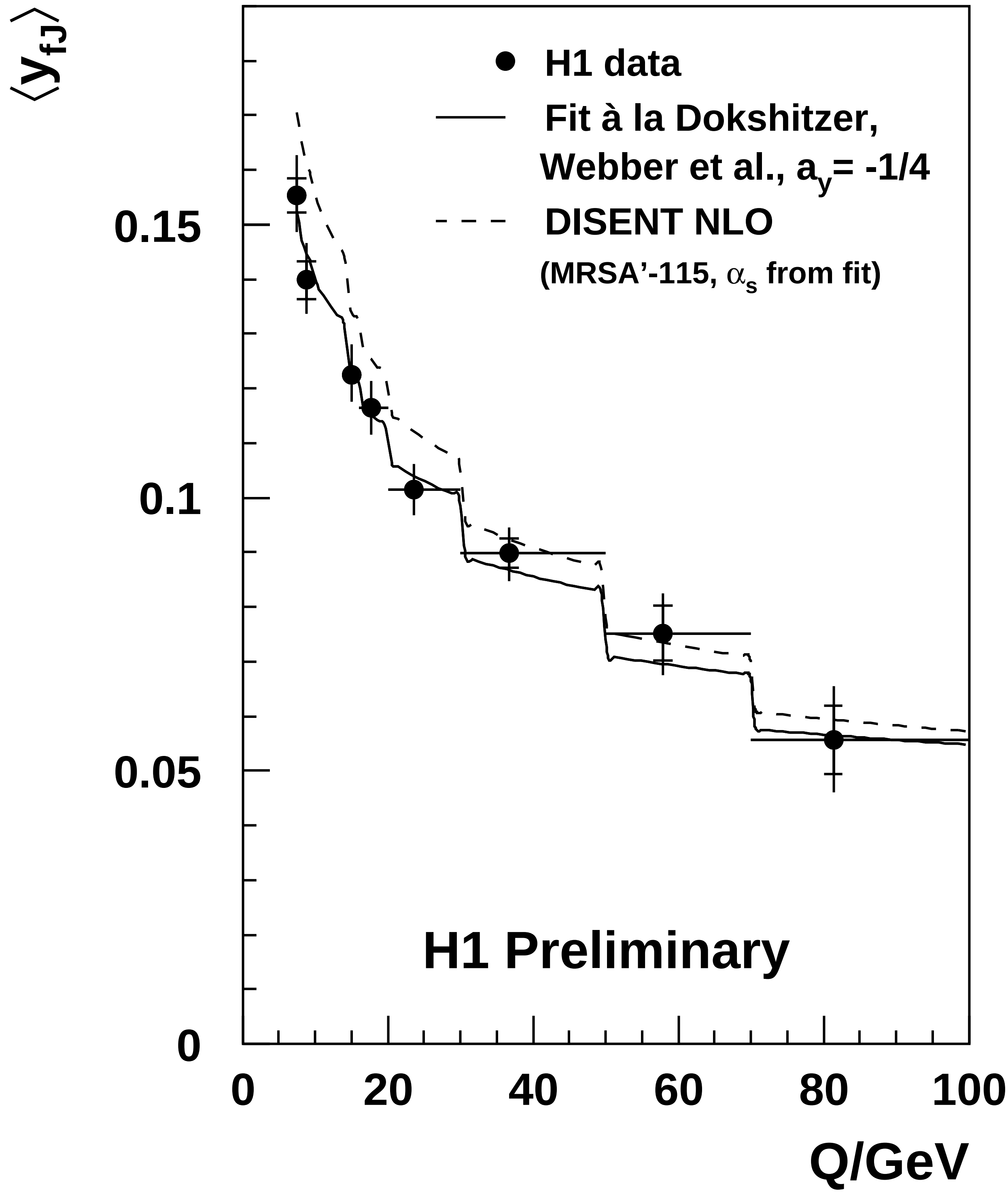
$(a'_B \propto 1/\sqrt{\alpha_s} + \mathrm{const.})$

Consistency Check



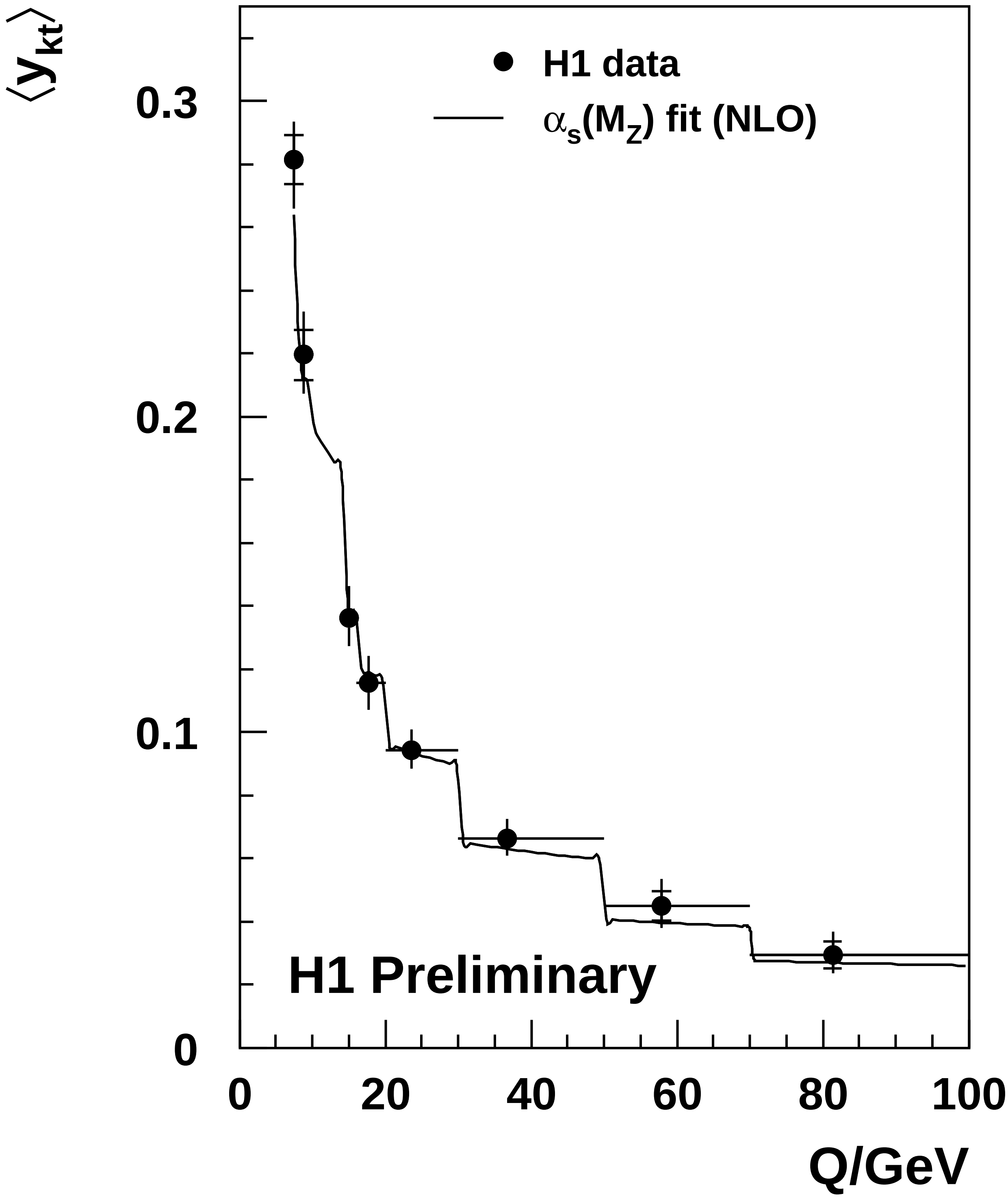
⇒ There is room for improvement, x dependent power corrections?

Fit to Means of y_{fJ} ($a_{y_{fJ}} = -1/4$)



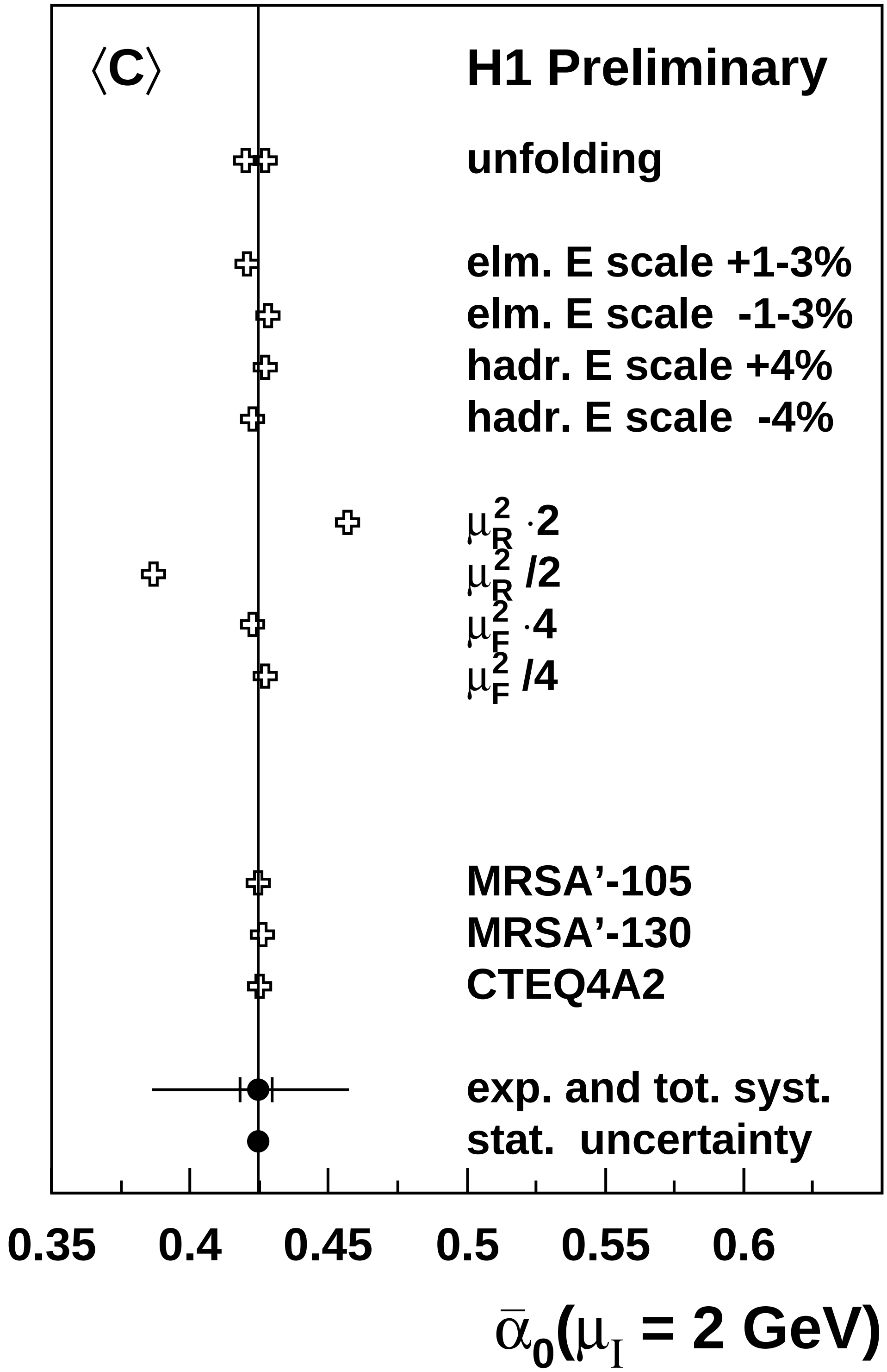
⇒ More reasonable results for $\overline{\alpha}_0$ and α_s from y_{fJ}.

Fit to Means of y_{k_t} ($\alpha_s(M_Z)$ only)

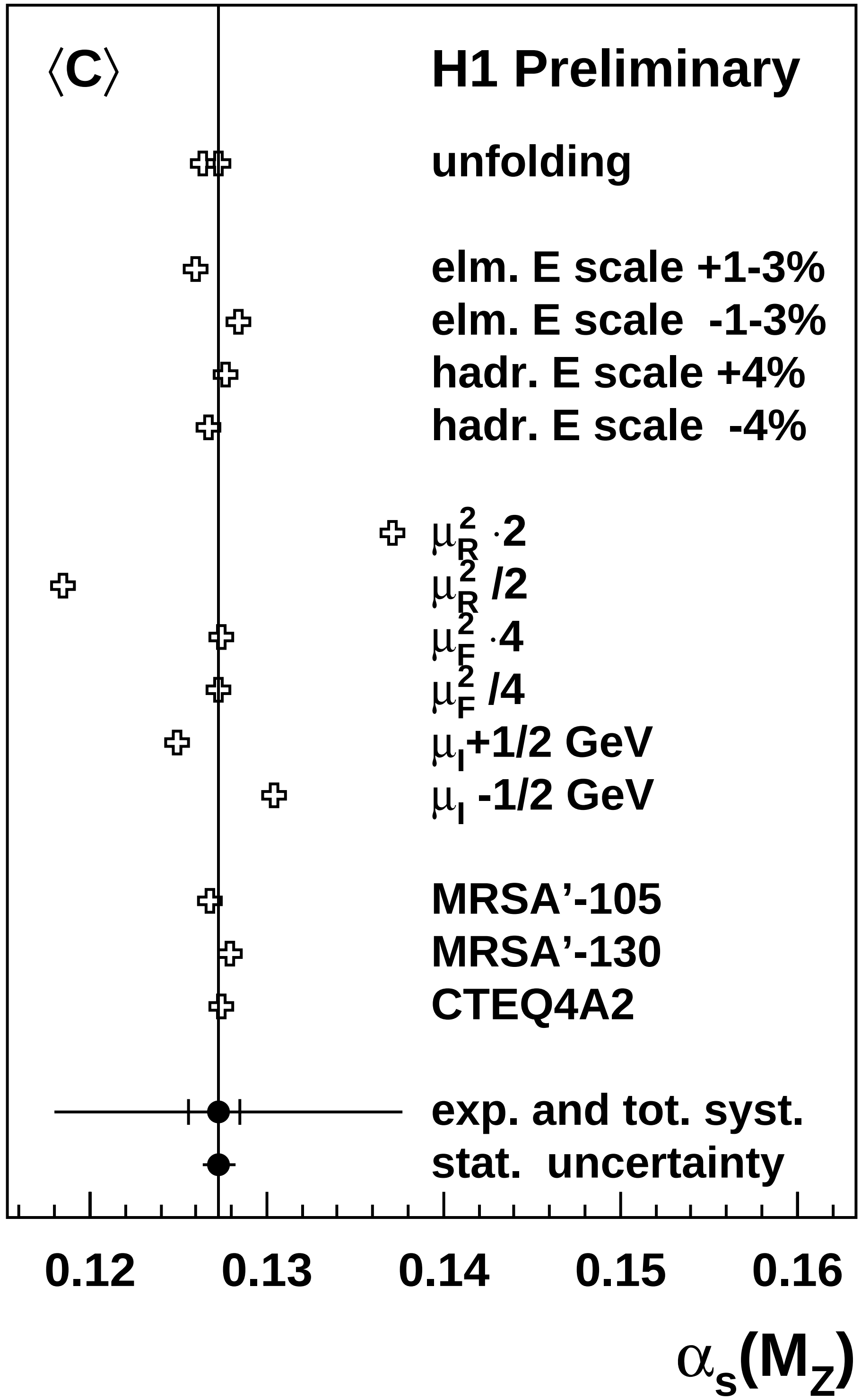


$1/Q$ fit unsatisfactory, 3-par. $1/Q^2$ fit instable, but acceptable fit for y_{k_t} without power term.

Systematic Uncertainties



Systematic uncertainties of $\overline{\alpha}_0(\mu_I = 2\,\mathrm{GeV})$ for C.



Systematic uncertainties of $\alpha_s(M_Z)$ for C.

Summary

- Substantially improved and extended analysis of event shape means, new variables, much more data.

- τ, B, ρ, τ_C, C sizably affected by hadronization, y_{fJ} and y_{k_t} exhibit small, negative hadronization corrections.

- Simple $\langle F \rangle^{\mathrm{pert}} + \lambda/Q$ or μ/Q^2 fits unsatisfactory

  $\Rightarrow$ x dependent λ, μ ?

- Power correction fits to Dokshitzer-Webber model much better, $\overline{\alpha_0} \approx 0.5 \pm 20\%$, but uncomfortably large spread in $\alpha_s(M_Z)$.

- New B coefficient works reasonably.

- Conjectured $a_{y_{fJ}} = 1$ coeff. excluded, $-1/4$ favoured.

- $1/Q$ fit unsatisfact. for $\langle y_{k_t} \rangle$, 3-par. $1/Q^2$ fit instable.

  $\Rightarrow$ More work to be done for y_2 variables.