Event Shapes and Power Corrections in ep DIS

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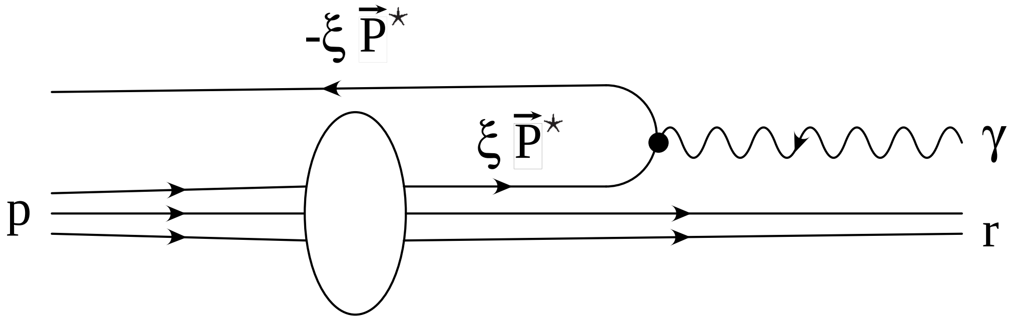
Outline

- Data on Event Shapes in the Current Hemisphere
- Problems with NLO Calculations
  (DISENT, DISASTER++)
- Fit of Distributions (without Resummation)
- Results with Event Shapes employing Jet Algorithms
- Summary

Definition of Event Shapes 1

CH



RH

QPM-type ep collision in the Breit frame.*

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

1−thrust:

$$\tau := 1 - \frac{\sum\limits_{i \in \mathrm{CH}} |\vec{p_i}^{\star} \cdot \vec{n}|}{\sum\limits_{i \in \mathrm{CH}} |\vec{p_i}^{\star}|} = 1 - \frac{\sum\limits_{i \in \mathrm{CH}} |p^{\star}_{li}|}{P^{\star}}$$

jet broadening:

$$B := \frac{\sum\limits_{i \in \mathrm{CH}} |\vec{p_i}^{\star} \times \vec{n}|}{2 \sum\limits_{i \in \mathrm{CH}} |\vec{p_i}^{\star}|} = \frac{\sum\limits_{i \in \mathrm{CH}} |p^{\star}_{ti}|}{2P^{\star}}$$

- 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

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

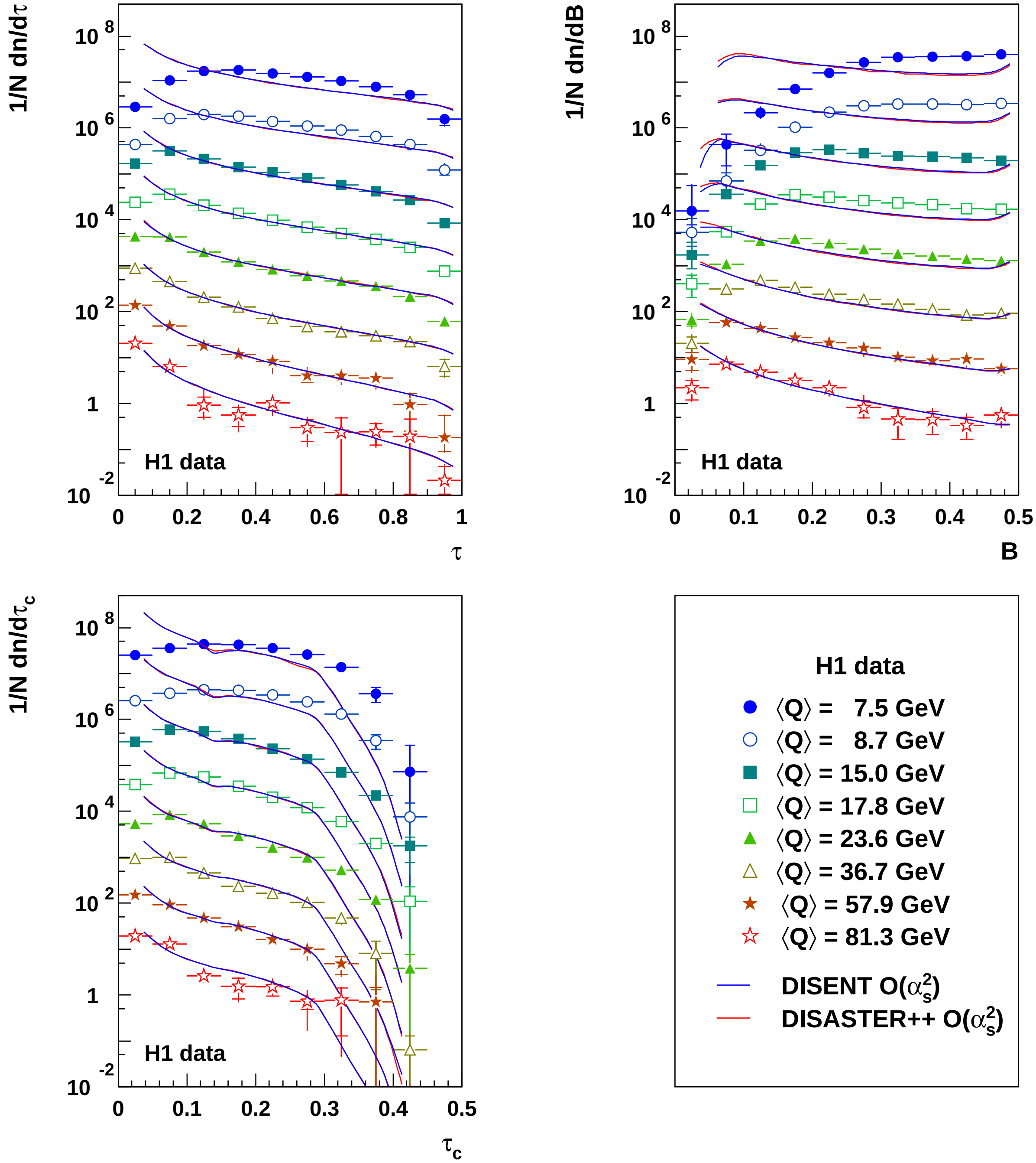
Phase Space and Data

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

(θ_q: Polar angle of QPM quark direction,
$E^\star$: Energy in the current hemisphere)

All data shown (event shape means and distributions) are taken from DESY-99-193, hep-ex/9912052!

Unfolded Distributions vs. NLO



Comparison of DATA and NLO pQCD

(DISENT: S.Catani/M.Seymour, DISASTER++: D.Graudenz)

$\Rightarrow$ Large discrepancies diminishing with rising Q.

$\Rightarrow$ For low Q, low B diff. between the NLO calc.!

Power Correction Formulae

Power correction to the means:

$$\langle F \rangle = \langle F \rangle^{\mathrm{pert}} + \mathcal{P} \,.$$

Power correction to the distributions (except for B)

$$\frac{1}{\sigma_{\mathrm{tot}}} \frac{d\sigma(F)}{dF} = \frac{1}{\sigma_{\mathrm{tot}}} \frac{d\sigma^{\mathrm{pert}}(F - \mathcal{P})}{dF} \,,$$

provided $\mu_I / Q \ll F$.

$\langle F \rangle$: pert = NLO

$\frac{d\sigma(F)}{dF}$: pert = NLO (Resummation!?)

$\mathcal{P}$ is given by

$$\mathcal{P} = a_F \frac{4C_F}{\pi\, p} \mathcal{M}' \left(\frac{\mu_I}{Q}\right)^p$$

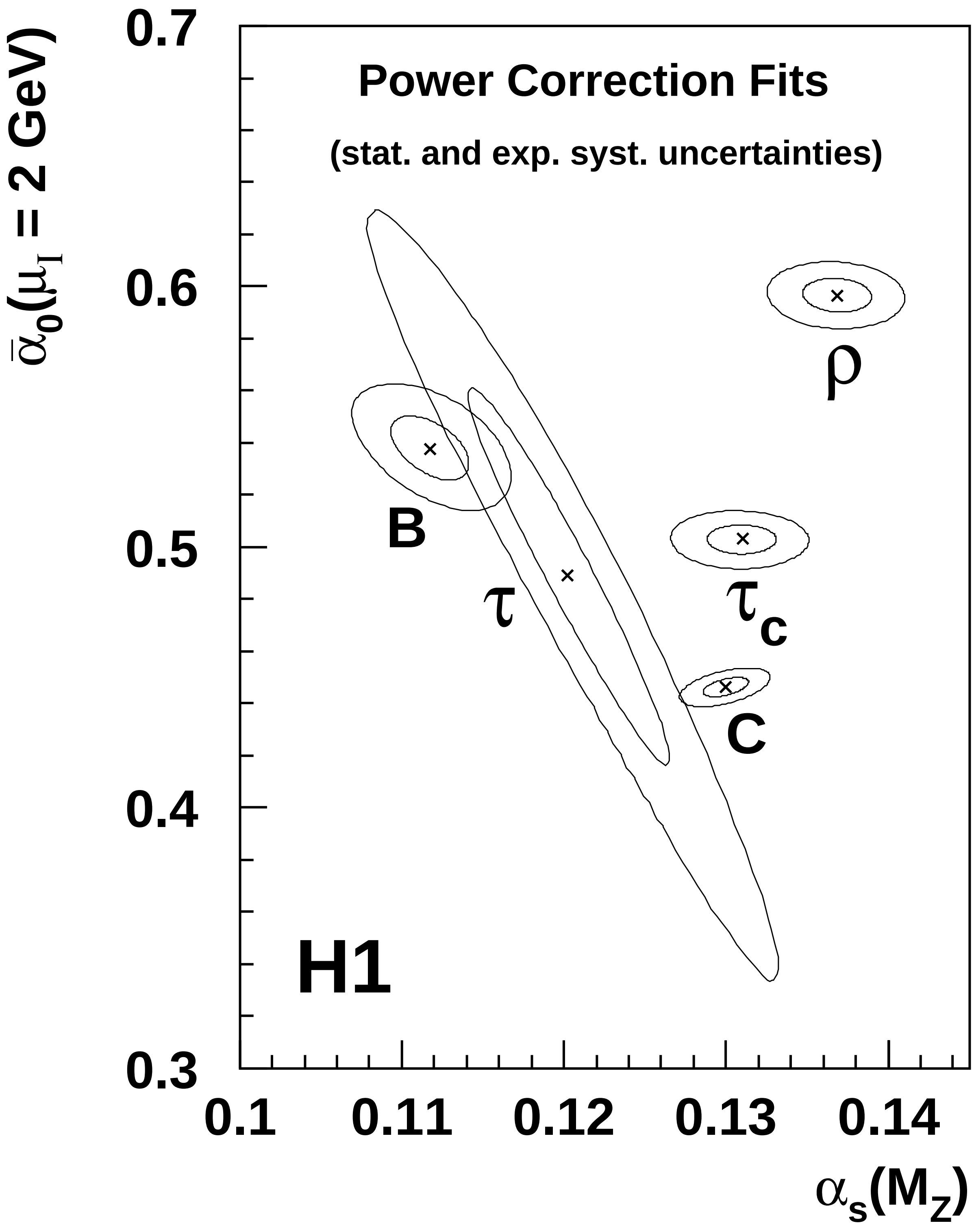
$$\left[\overline{\alpha}_{p-1}(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\pi}\left(\ln\frac{Q}{\mu_I} + \frac{K}{\beta_0} + \frac{1}{p}\right)\alpha_s^2(Q)\right]$$

with

$\overline{\alpha}_{p-1}(\mu_I)$: universal (?) non-pert. parameter

p: power $p = 1$ except for y_{k_t} where $p = 2$.

Fits to $\langle F \rangle$ using DISENT



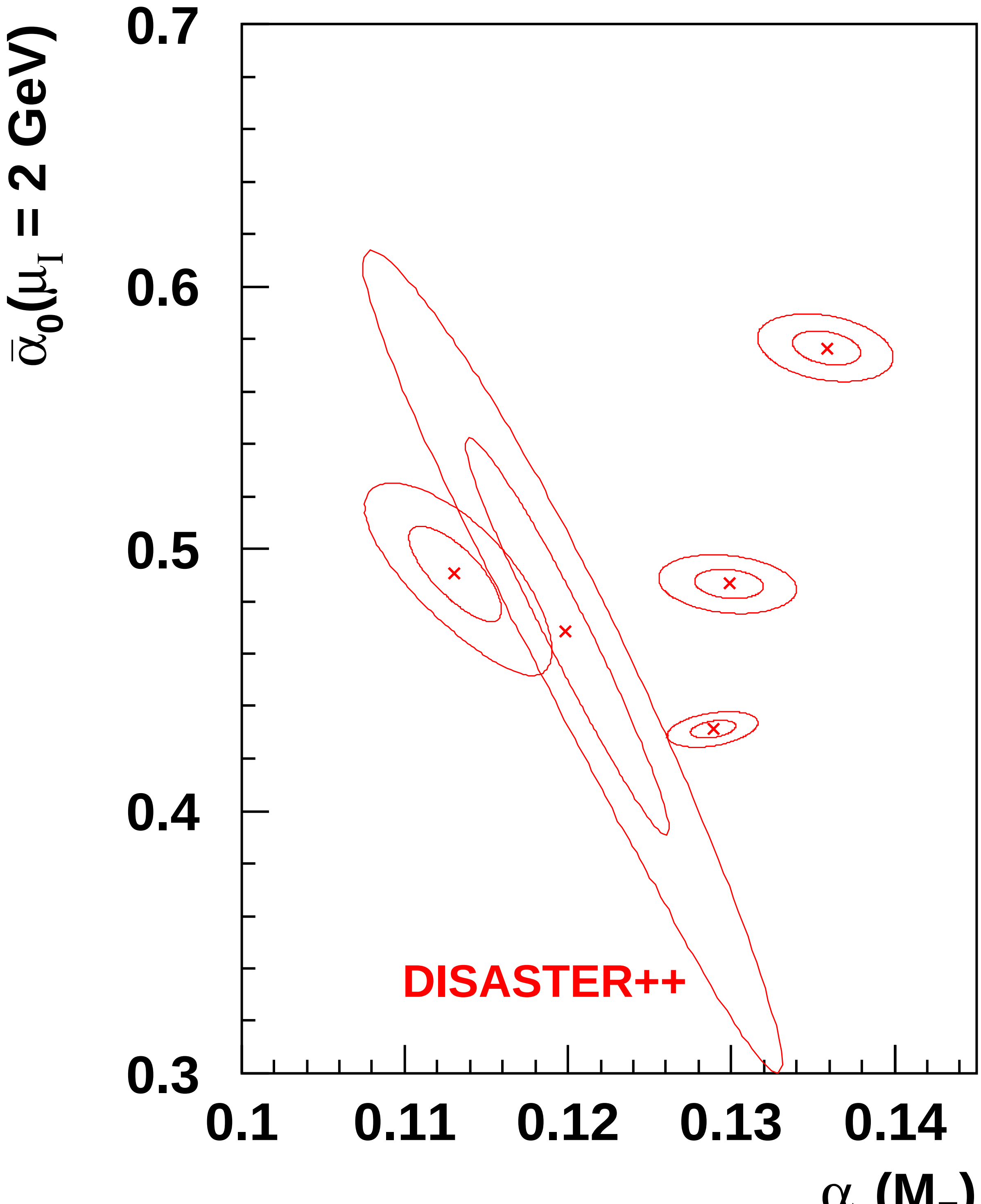
Uncomfortably large spread in $\alpha_s(M_Z)$!

Fit Results for the Power Corrections

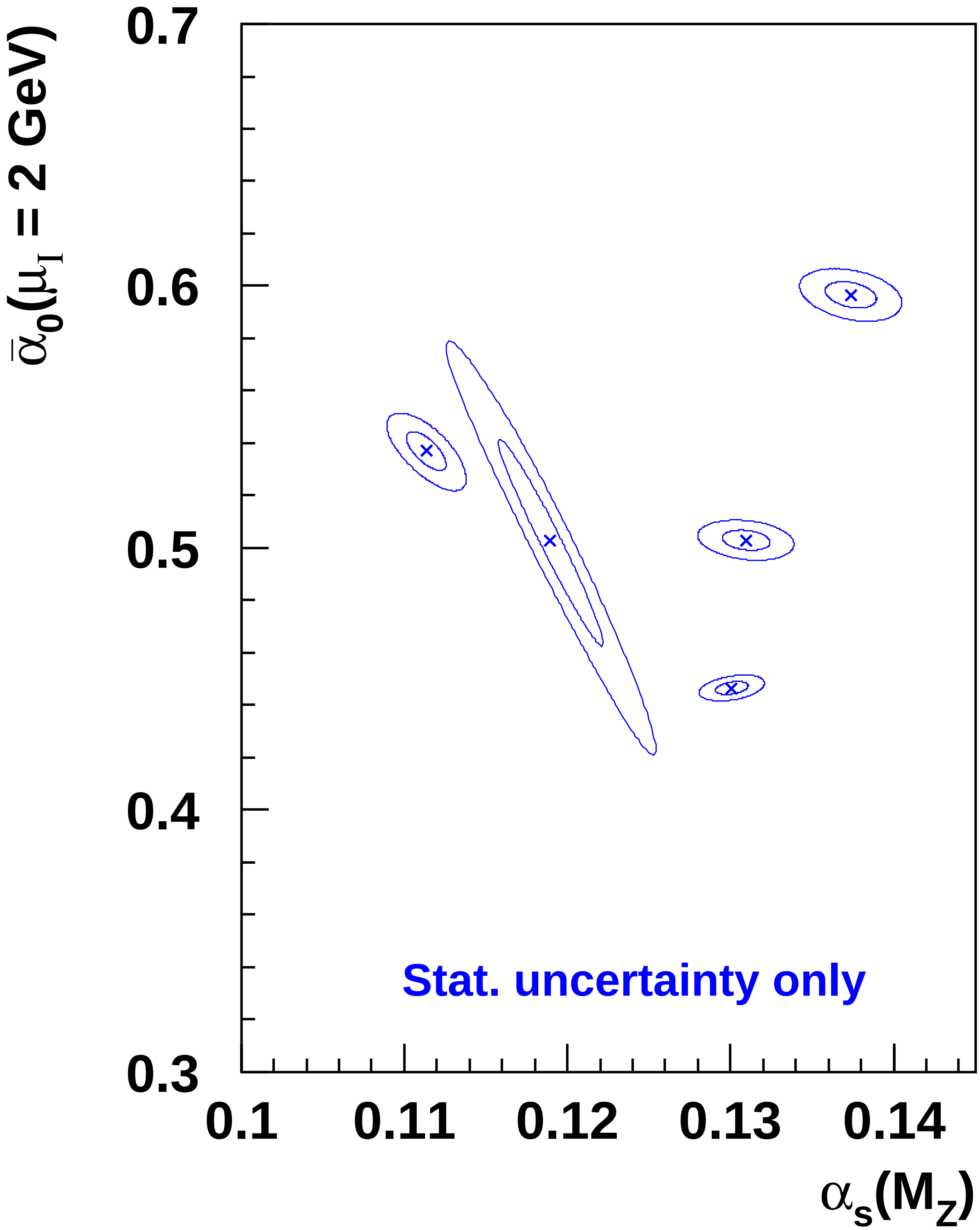
H1 Data					
$\langle F \rangle$	a_F	$\overline{\alpha}_0(\mu_I = 2\,\mathrm{GeV})$	$\alpha_s(M_Z)$	χ^2/n	$\kappa/\%$
$\langle \tau \rangle$	1	$0.503\ ^{+0.043}_{-0.053}\ ^{+0.053}_{-0.068}$	$0.1190\ ^{+0.0075}_{-0.0054}\ ^{+0.0073}_{-0.0069}$	0.5	-98
$\langle B \rangle$	$1/2 \cdot a'_B$	$0.537\ ^{+0.017}_{-0.012}\ ^{+0.028}_{-0.039}$	$0.1113\ ^{+0.0036}_{-0.0028}\ ^{+0.0049}_{-0.0051}$	0.7	-69
$\langle \rho \rangle$	$1/2$	$0.597\ ^{+0.009}_{-0.010}\ ^{+0.050}_{-0.057}$	$0.1374\ ^{+0.0024}_{-0.0032}\ ^{+0.0110}_{-0.0096}$	1.1	-32
$\langle \tau_C \rangle$	1	$0.503\ ^{+0.008}_{-0.010}\ ^{+0.043}_{-0.047}$	$0.1310\ ^{+0.0023}_{-0.0028}\ ^{+0.0098}_{-0.0089}$	1.2	-22
$\langle C \rangle$	$3\pi/2$	$0.447\ ^{+0.005}_{-0.007}\ ^{+0.032}_{-0.038}$	$0.1301\ ^{+0.0016}_{-0.0020}\ ^{+0.0103}_{-0.0091}$	0.8	$+36$

$\Rightarrow$ All $1/Q$ fits including B work reasonably.

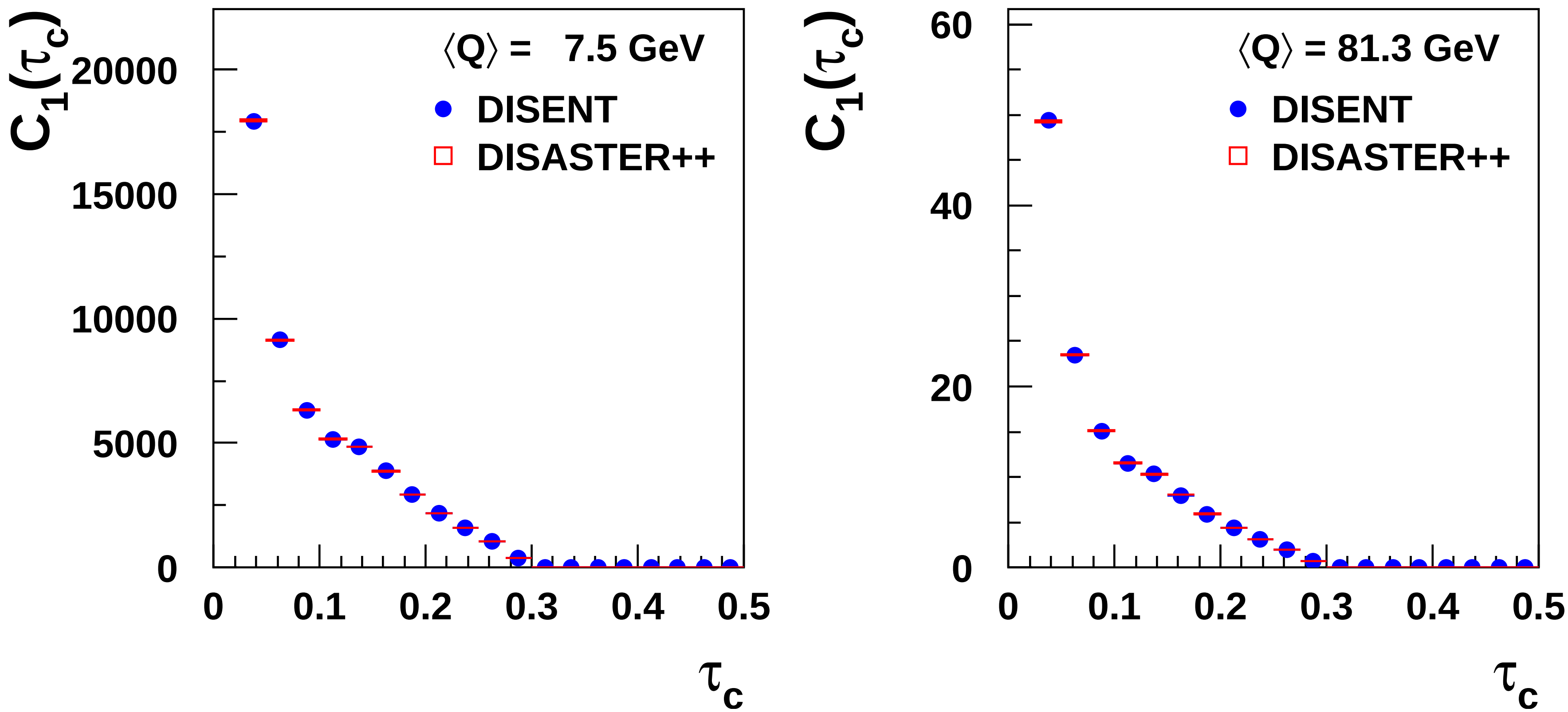
$(a'_B \propto 1/\sqrt{\alpha_s} + \mathrm{const.})$



0.7
0.6
0.5
0.4
0.3
$\bar{\alpha}_0(\mu_I = 2\ \mathrm{GeV})$
DISASTER++
0.1
0.11
0.12
0.13
0.14
$\alpha_s(M_Z)$


0.7
0.6
0.5
0.4
0.3
0.1
0.11
0.12
0.13
0.14
$\bar{\alpha}_0(\mu_I = 2$ GeV)
$\alpha_s(M_Z)$
Stat. uncertainty only

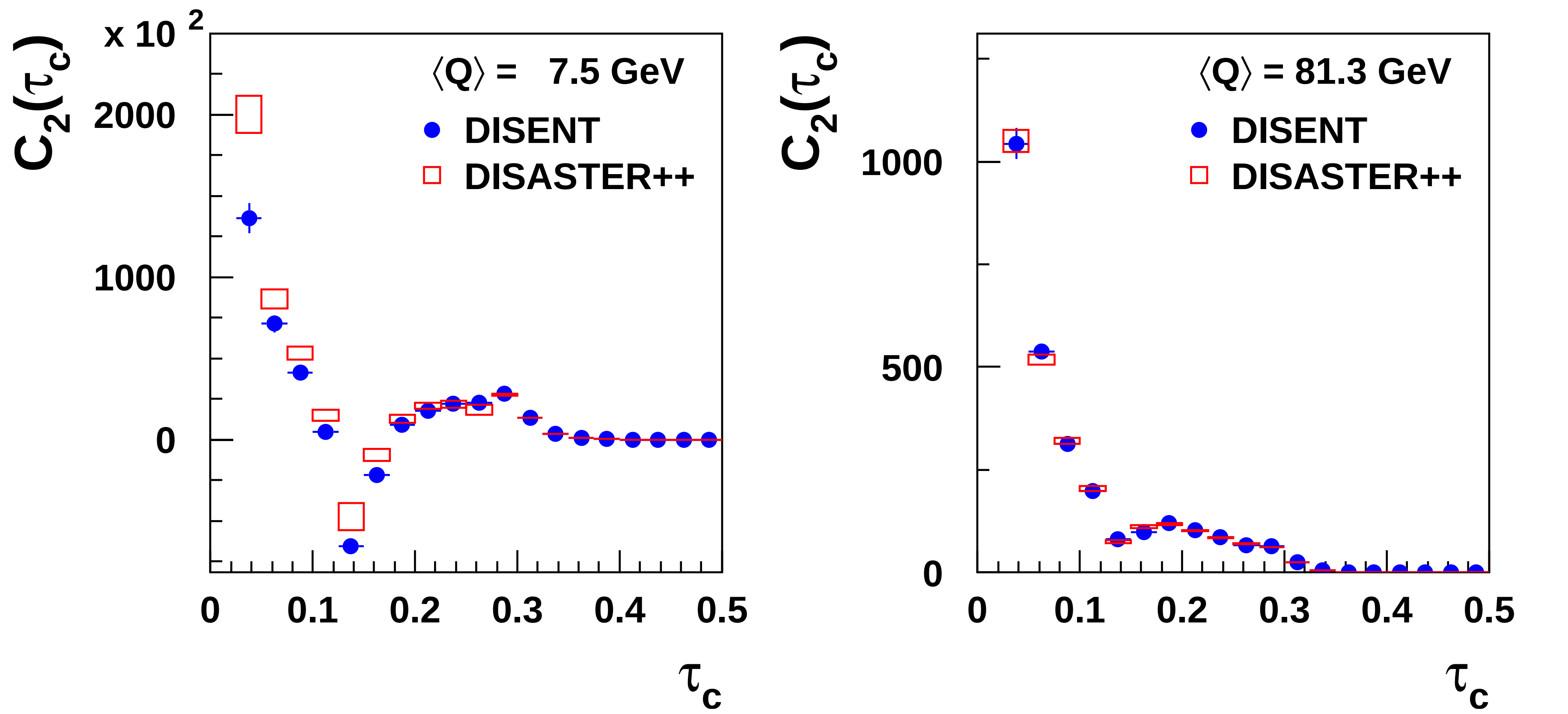
LO $C_1(\tau_C)$ Coefficient Function



Perturbative expansion: $d\sigma/dF = C_1(F)\,\alpha_s(Q)/(2\pi) + C_2(F)\,\alpha_s^2(Q)/(4\pi^2)$.

DISENT and DISASTER++ agree perfectly $\Rightarrow$ No problem here.

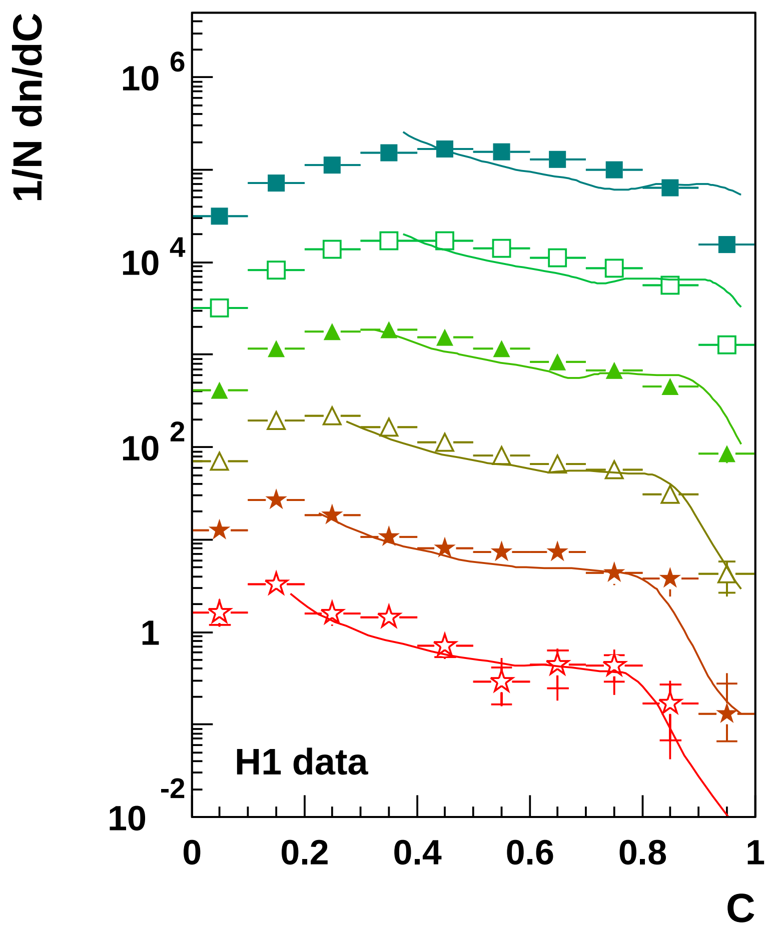
NLO $C_2(\tau_C)$ Coefficient Function

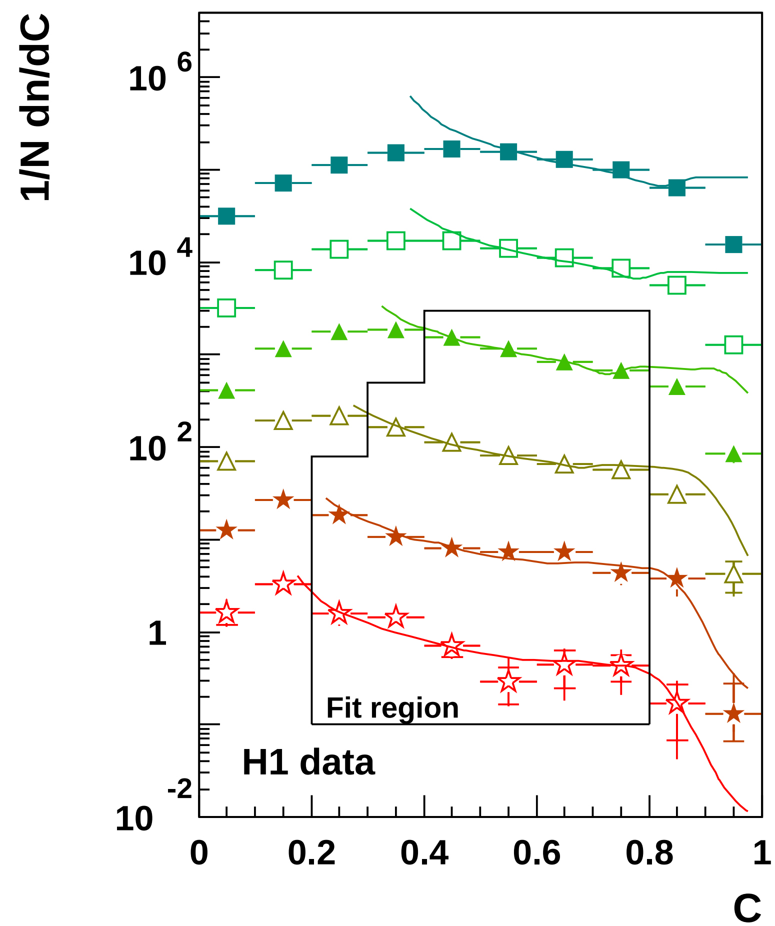


Severe discrepancies observed! $\Rightarrow$ Which one (if any) is right?

BTW: CPU time ($400\,\mathrm{MHz}$ P3): DISENT: $\approx$ 20 days, DISASTER++: $\approx$ 100 days

Comparison of Fits to $1/N\, dn/dC$

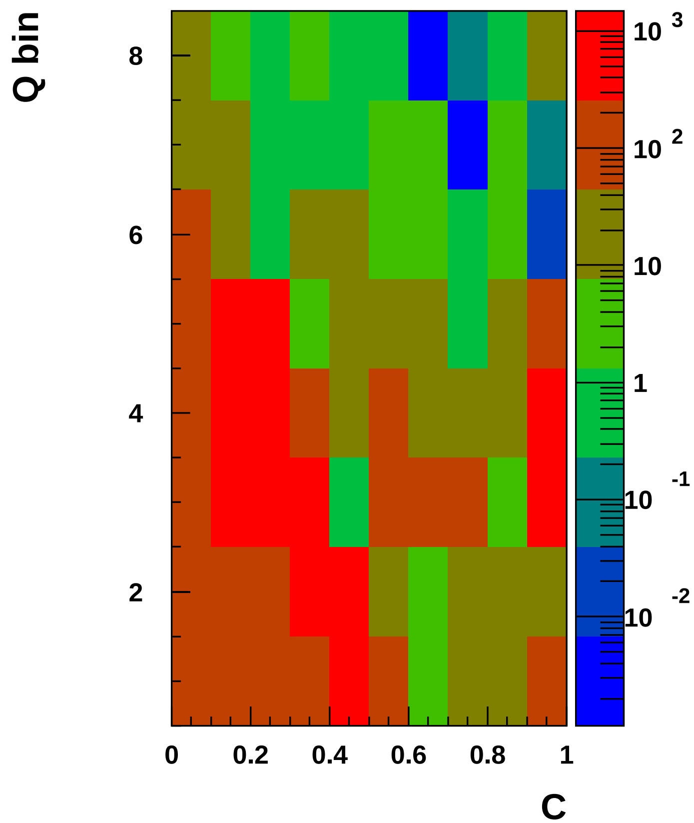


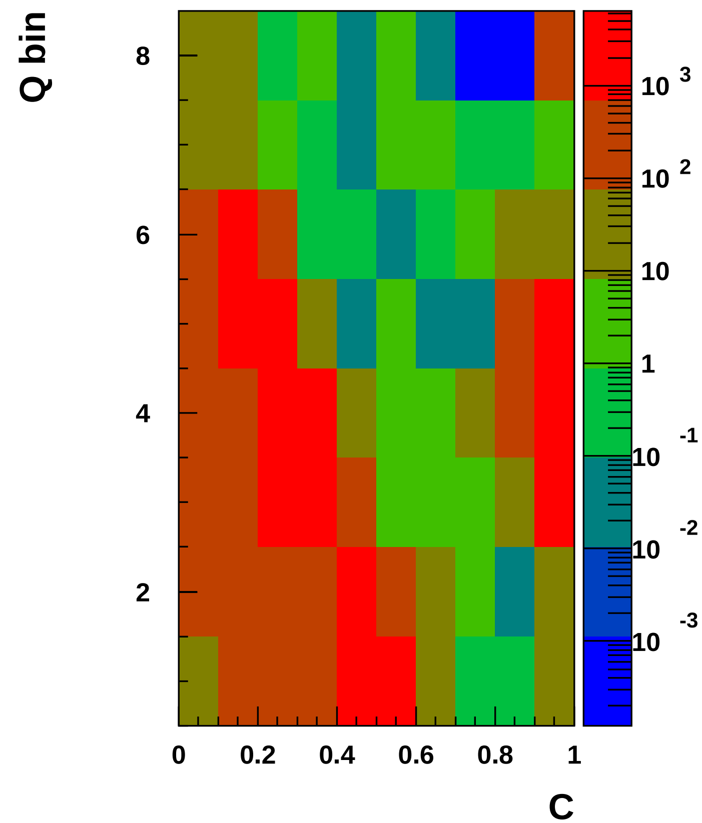


Left: Fit of $\overline{\alpha}_0$, $\alpha_s(M_Z)$ to the means: 0.45, 0.130

Right: Fit of $\overline{\alpha}_0$, $\alpha_s(M_Z)$ to the distr.: 0.62, 0.131 $\Rightarrow$ Different answers!

χ^2 Contribution of Individual Points





χ^2 contributions for the description of C from power corrections deduced from means (left) and distributions (right).

Definition of Event Shapes 2

- Event shapes employing jet algorithms:

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

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

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

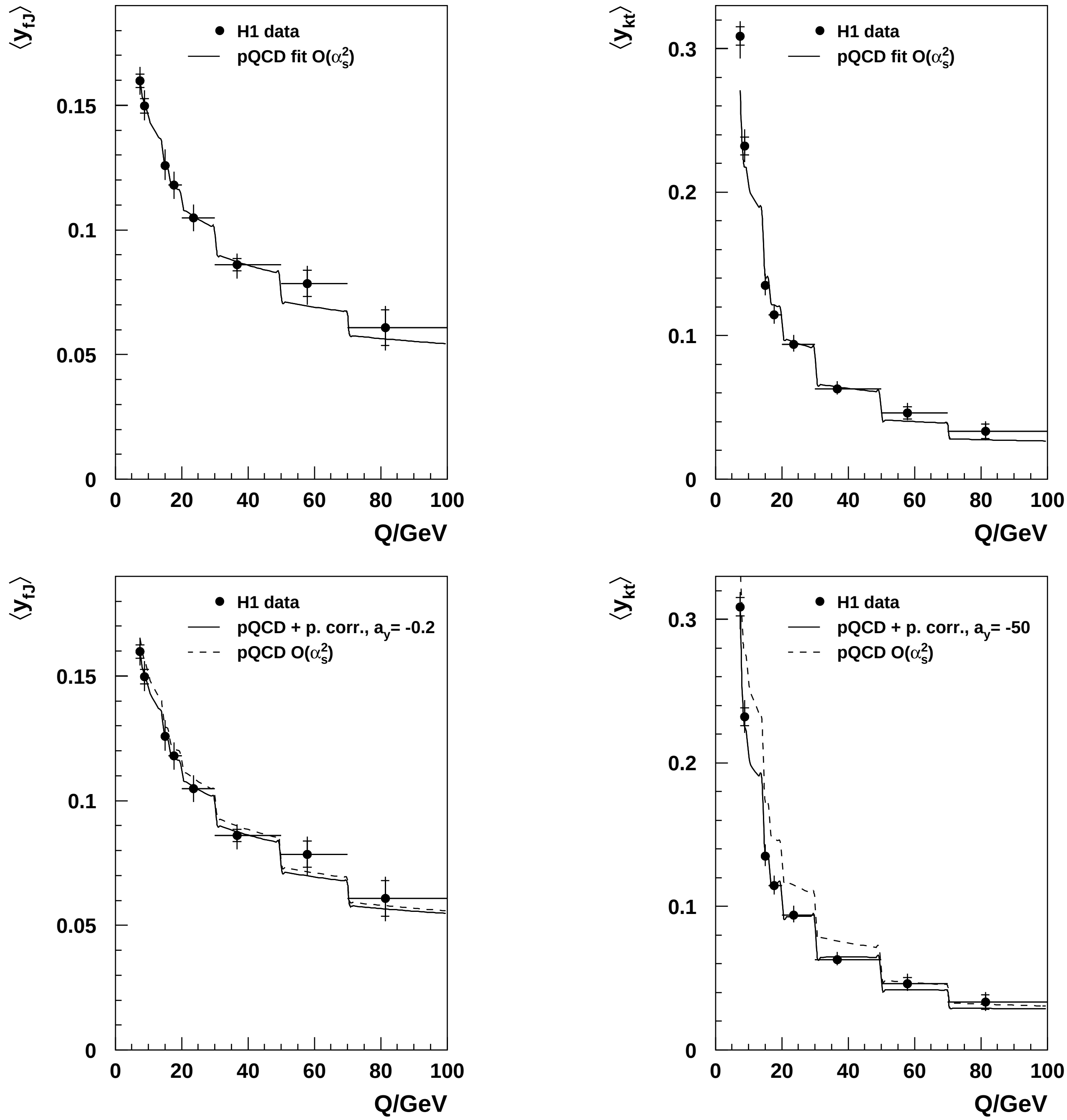
  and the k_t algorithm

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

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

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

Fits to Means of y_{fJ} and y_{k_t}

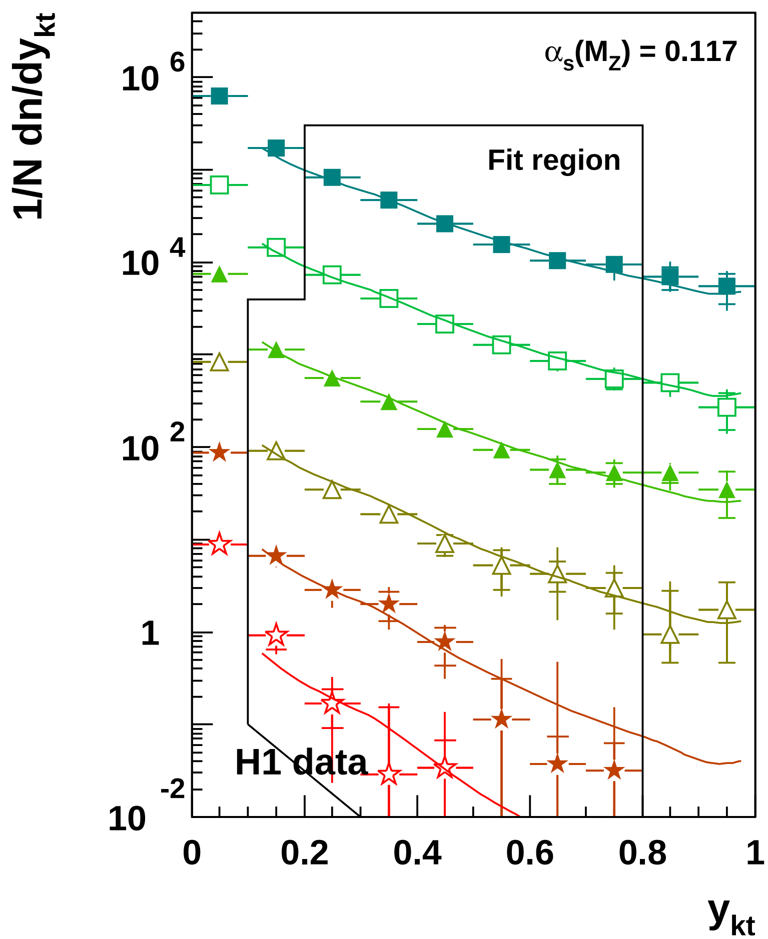


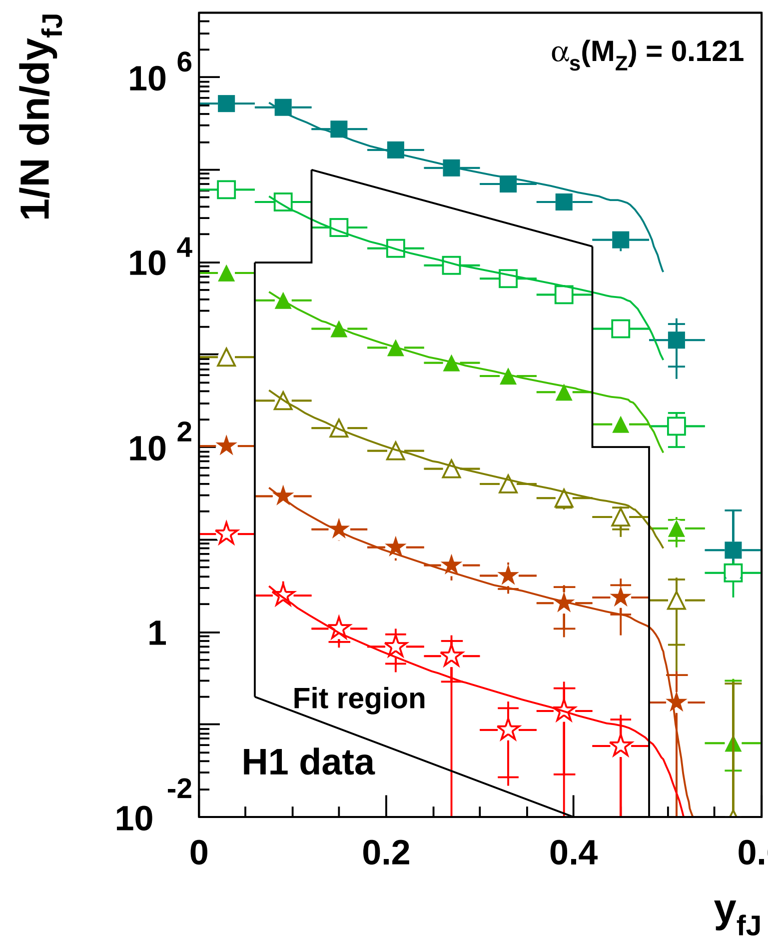
Upper plots: Fits of pQCD without power correction

Lower plots: Fits with power corrections,

$$a_{y_{fJ}} = -0.2,\ a_{y_{k_t}} = -50$$

NLO Fits to $1/N\ dn/dy_{k_t}$ and $1/N\ dn/dy_{fJ}$





Neglect of small hadronization corrections.
Reasonable fit results for $\alpha_s(M_Z)$.

Summary

- Reasonable results from power correction fits to event shape means: $\overline{\alpha_0} \approx 0.5 \pm 20\%$, but uncomfortably large spread in $\alpha_s(M_Z)$.

- Fortunately, serious discrepancies between DISENT and DISASTER++ only lead to a 2σ decrease in $\overline{\alpha}_0$. Which program, if any, is right?

- Power correction fits to event shape distributions (without resummation) are not consistent with results from means, large values of both, $\overline{\alpha}_0$ and $\alpha_s(M_Z)$, are preferred.
  Can resummed predictions help?

- Event shapes employing jet algorithms, i.e. y_{k_t} and y_{fJ}, exhibit small hadronization corrections. Conjectured $a_{y_{fJ}} = 1$ coeff. excluded, ≈ -0.2 favoured.
  Fits of $\alpha_s(M_Z)$ to means and distributions give very reasonable results even without power correction.