Measurement of Event Shapes in DIS

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on behalf of

The ZEUS Collaboration

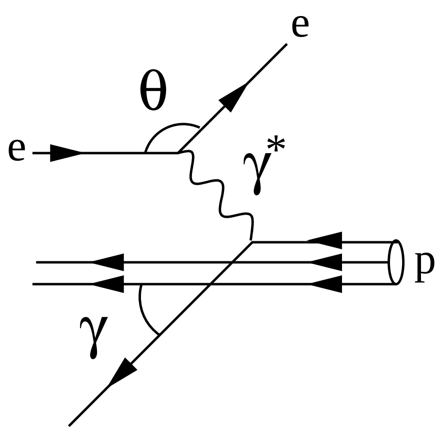
Outline:

- Introduction
- Fits to Mean Event Shape Data
- Fits to Differential Event Shape Distributions
- Addition of NLL Resummations to Fits
- Conclusions

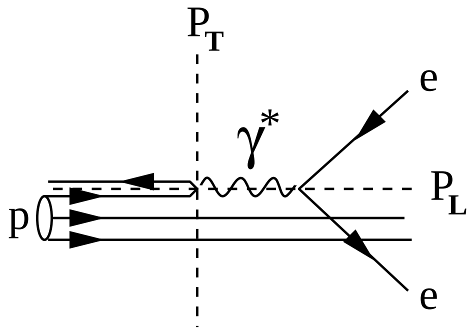
Event Shape Analysis

- Event Shape Variables measure aspects of the topology an event's hadronic final state.
- Event Shapes in DIS should allow investigation of QCD over a wide range of energy scales.
- ... but hadronisation corrections are large for these variables.
- *Power Correction* model seeks to describe the effect of hadronisation on these variables.

- Measure event shapes in the *Breit Frame*
  - Largest possible separation between proton and scattered quark.
  - Select hadrons in Lab frame, then boost to Breit frame. Correct with MC.
  - Current Region is analogous to single e^+e^- hemisphere.



Lab Frame



Breit Frame

Event Shape Variables

Measurement Phase Space : 80 GeV$^2 < Q^2 < 20480$ GeV^2 and $0.04 < y < 0.9$.

Axis dependent:

$$T = \frac{\sum_i |\vec{p}\,.\,\vec{n}|}{\sum_i |\vec{p}\,|}$$

Thrust

$$B = \frac{\sum_i |\vec{p} \times \vec{n}|}{\sum_i |\vec{p}\,|}$$

Broadening

- Thrust - longitudinal momentum sum.
- Broadening - transverse momentum sum.

Both the above are measured with $\vec{n}$ set to Thrust Axis and Photon Axis.

Independent of axis:

$$M^2 = \frac{\left(\sum_i p^\mu\right)^2}{\left(2\sum_i E\right)^2}$$

Jet Mass

$$C = \frac{3\sum_{ij} \vec{p_i}\vec{p_j} \sin^2(\theta_{ij})}{2\sum_{ij} \vec{p_i}\vec{p_j}}$$

C Parameter

- Jet Mass and C parameter
  - correlations of pairs of particles.

Sums are over all momenta in the *Current Region* of the Breit frame.

Variables are calculated in the p-scheme.

Power Correction Model

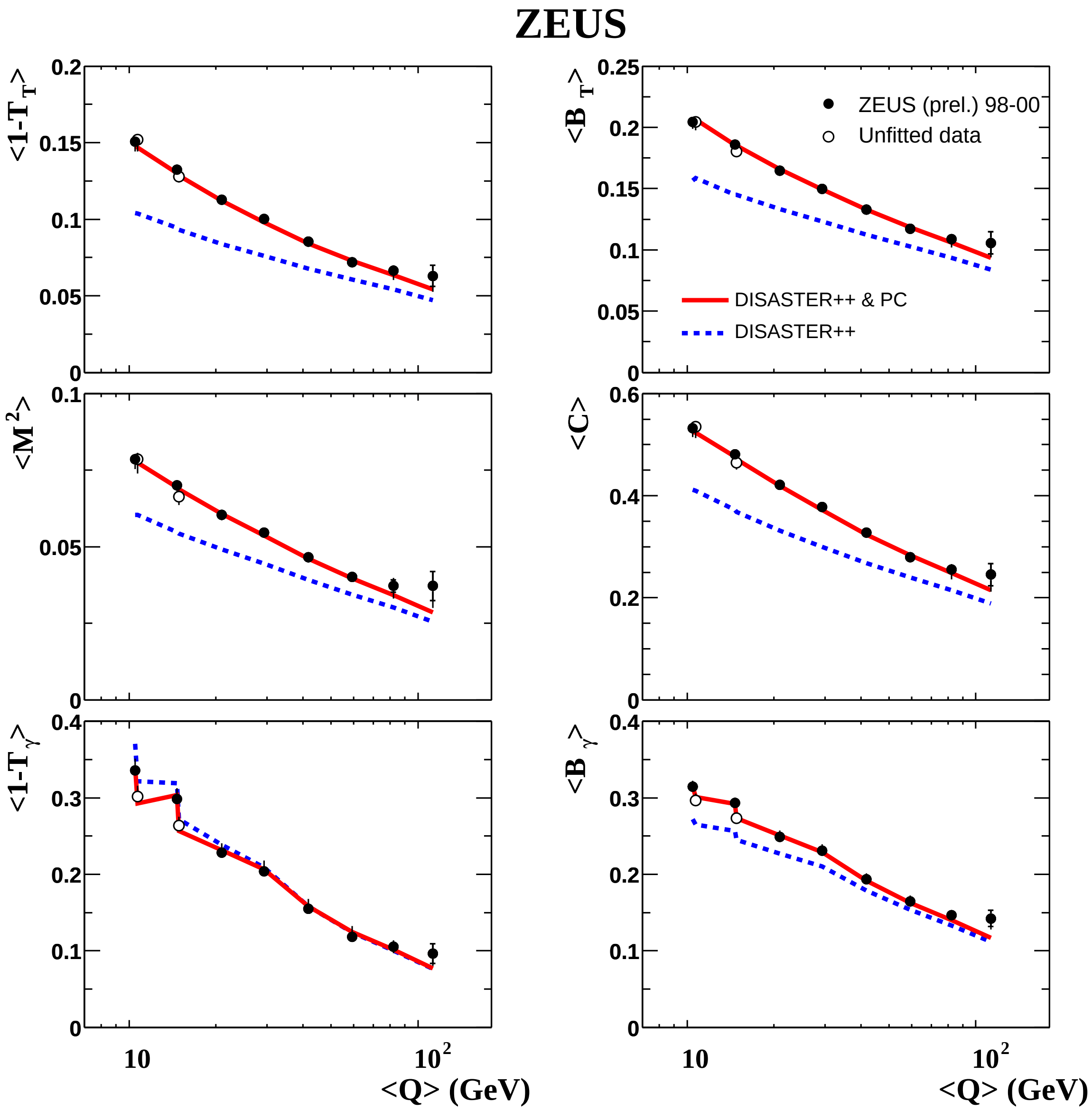
- $< F > = < F >_{\mathrm{NLO}} + < F >_{\mathrm{pow}}$
- $< F >_{\mathrm{NLO}}$ is calculated by DISASTER++.
- $< F >_{\mathrm{pow}}$ is a correction to account for hadronization.
- Introduce a new parameter $\overline{\alpha_0}$ to describe non-perturbative effects.

$$\overline{\alpha_0} = \frac{1}{\mu_I} \int_0^{\mu_I} \alpha_{\mathrm{eff}}(\mu_R) d\mu_R$$

$$< F >_{\mathrm{pow}} \propto \frac{1}{Q} \left[\overline{\alpha_0} - \alpha_S(\mu_R) - \frac{\beta_0}{2\pi} \left(\ln\left(\frac{\mu_R}{\mu_I}\right) + \frac{K}{\beta_0} + 1 \right) \alpha_S^2(\mu_R) \right]$$

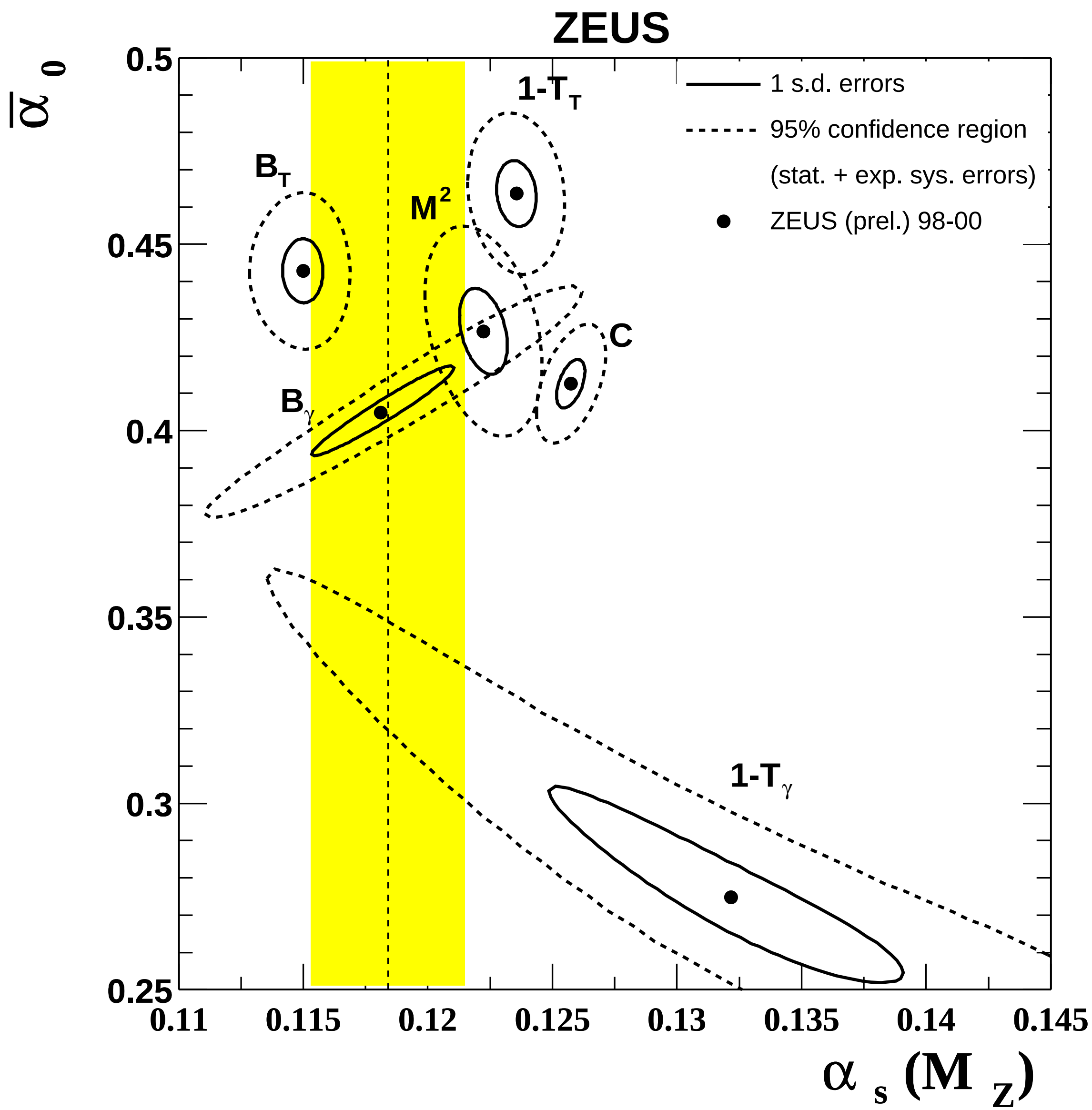
- Fit for $\alpha_S(M_Z)$ and $\overline{\alpha_0}$.

NLO + Power Correction Fits to Means



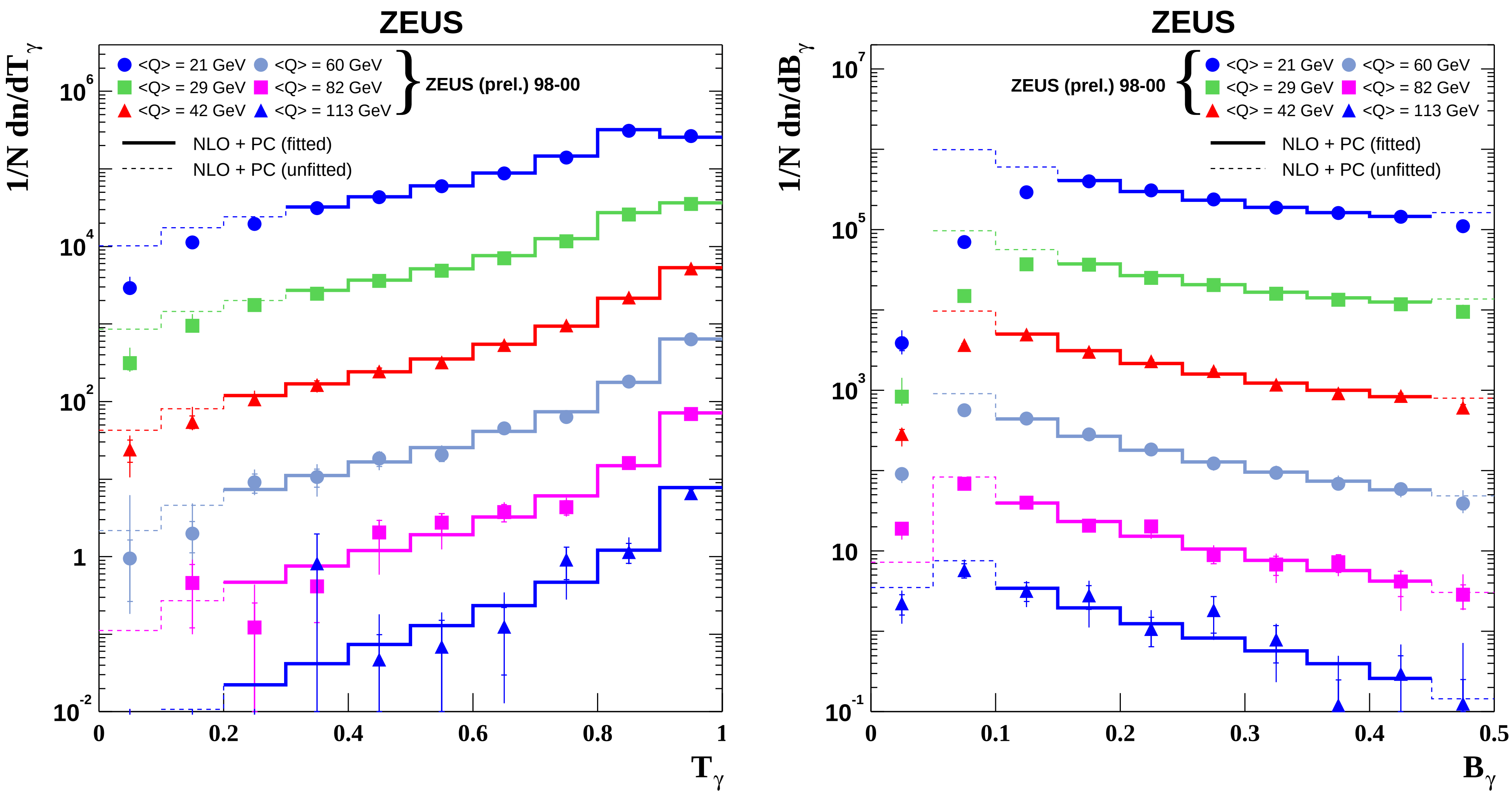
- Fits use Hessian method for statistical and systematic errors.
- High-x data points (open circles) are not fitted.
- All variables fitted with a good χ^2.
- Photon axis variables (esp. $1 - T_\gamma$) show large x-dependence.
- $1 - T_\gamma$ correction very small and negative.
- Model describes data well.

NLO + Power Correction Fits to Means



- $1 - T_\gamma$ fit poorly defined
  - large systematic errors.
- Fitted α_s values consistent to within 5%.
- Fitted $\overline{\alpha}_0 \simeq$ 0.45 to within 10%.
- Theory errors dominate, except for γ axis variables.
- Consistent with previous ZEUS measurement (Eur. Phys. J. 2003).

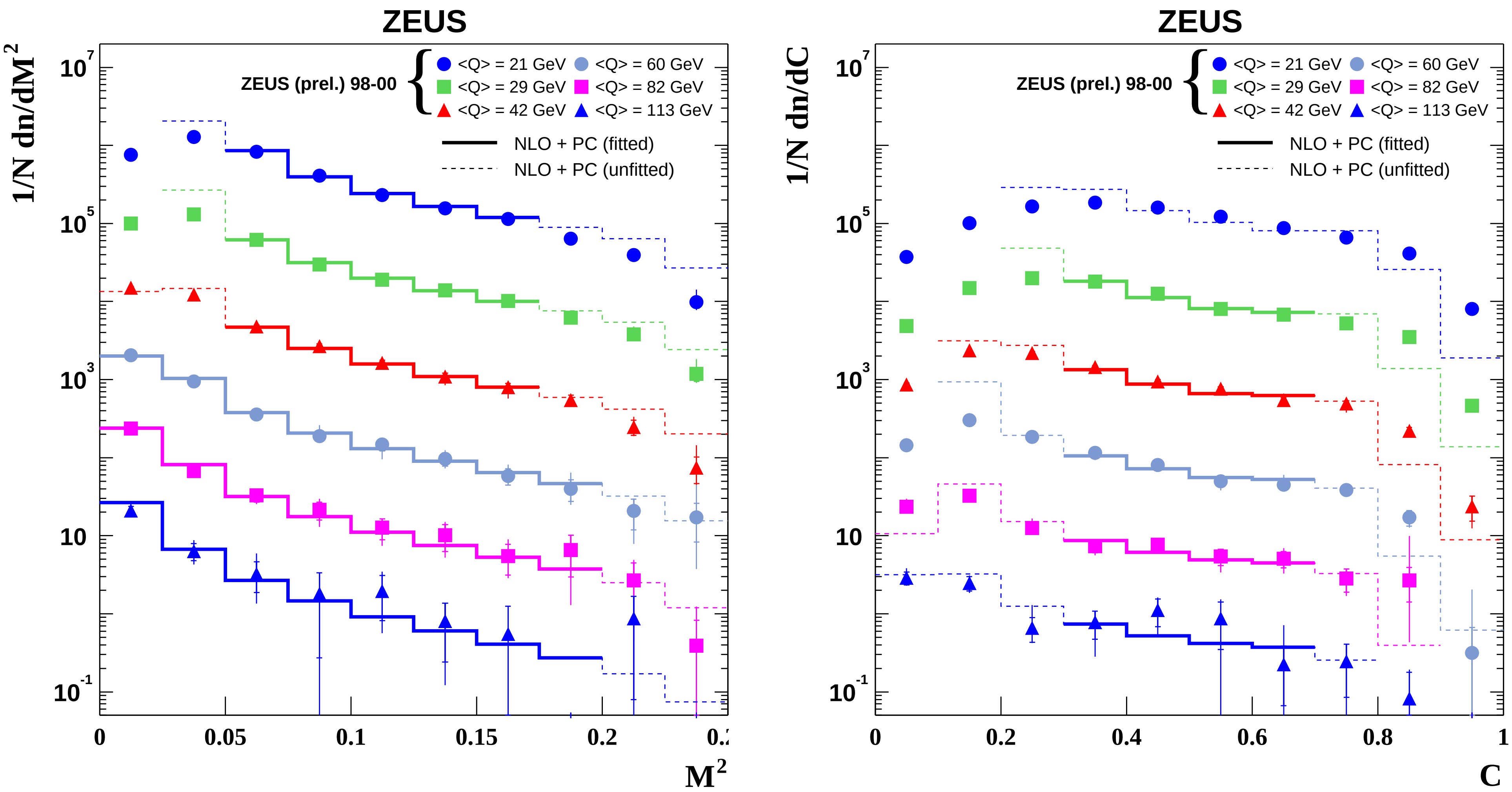
NLO + PC Fits to Differential Distributions



- Power Correction is interpreted as a 'shift' in the NLO distribution.

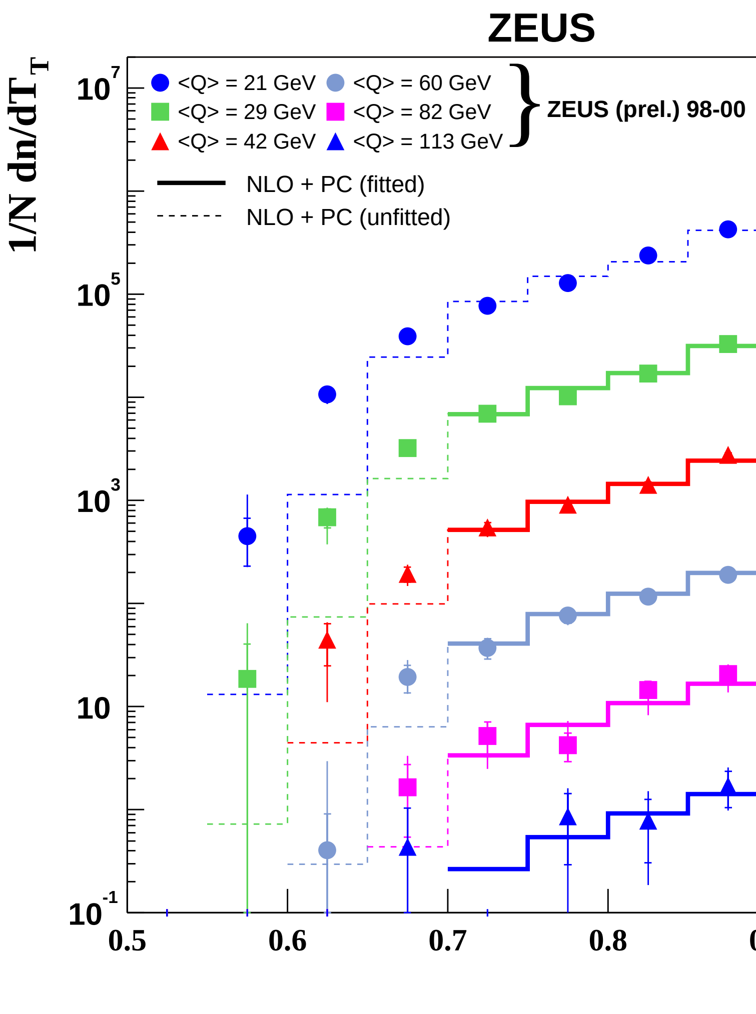
$$\frac{1}{N}\frac{dn}{dF}(F) = \frac{1}{N}\frac{dn_{\rm NLO}}{dF}(F - F_{\rm pow})$$

NLO + PC Fits to Differential Distributions



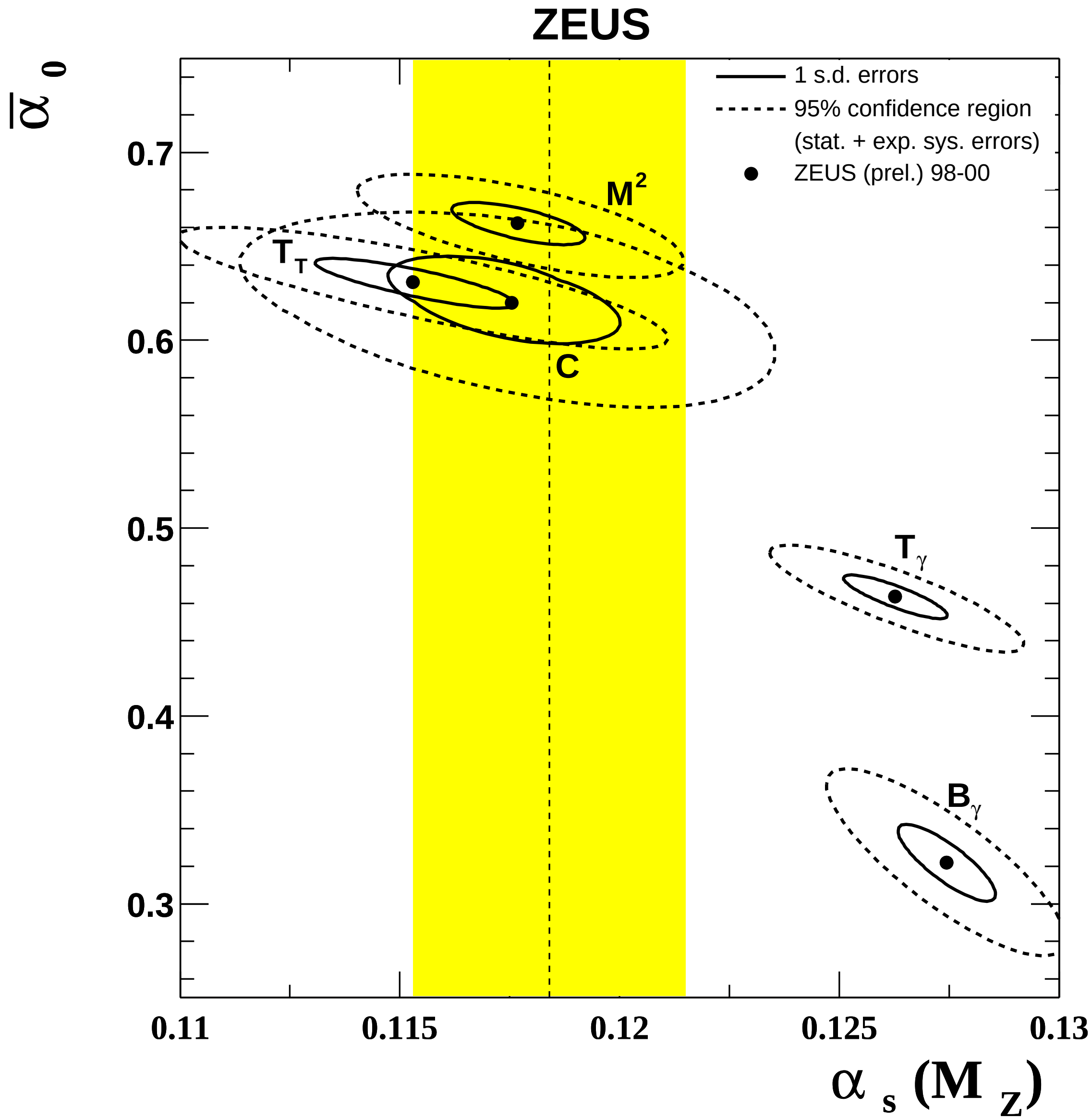
- Fit in central range of distributions, where fixed-order calculations are valid.

NLO + PC Fits to Differential Distributions



- Fit differential distributions over limited range.
- Usable range increases with Q^2.
- All variables fitted with reasonable χ^2.
- No B_T fit - no resummation or matching available.
- Fits performed using the DISRESUM package.

NLO + PC Fits to Differential Distributions



- Fits use Hessian method for statistical and systematic errors.
- Photon axis variables fit with high α_s...
- ...but other variables consistent in α_s and $\overline{\alpha}_0$.
- Fits $\overline{\alpha}_0$ somewhat high compared to that from means.

NLL Resummations

- In the $1 + 1$ jet limit, large logarithmic terms cause event shape variables to converge poorly.
- A Resummation sums the dominant terms of the perturbative series at all orders of α_s.
- A schematic NLL resummed integral cross section:

$$d^2\sigma_r(x, Q^2, F) = \left[\mathbf{C}_0 + \bar{\alpha}_{\mathrm{S}}(Q^2)\mathbf{C}_1\right] e^{Lg_1(\alpha_{\mathrm{S}}\beta_0 L) + g_2(\alpha_{\mathrm{S}}\beta_0 L)}$$

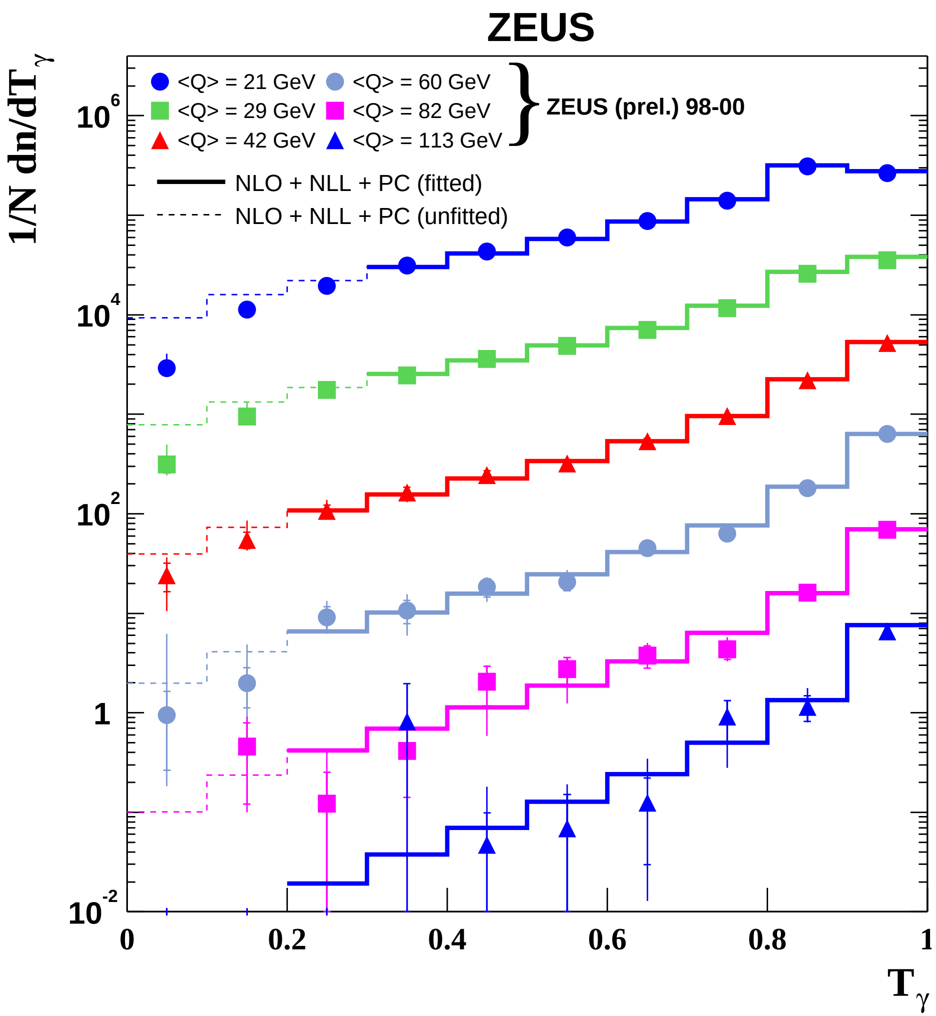
LL NLL

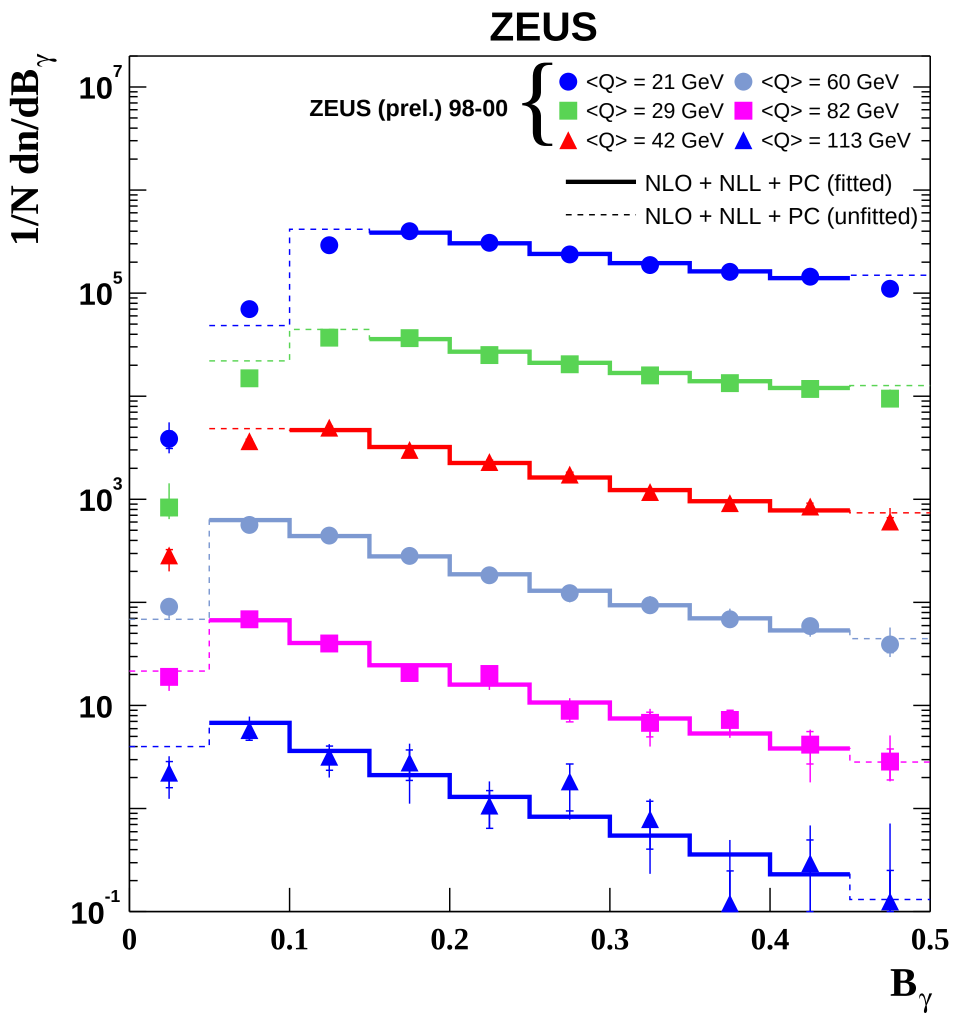
- To combine with NLO calculations, need to remove the parts of the fixed-order calculation already counted in the resummation: Matching.

$$\sigma(F) = \sigma_r + \bar{\alpha}_{\mathrm{S}}(\sigma_e^{(1)} - \sigma_r^{(1)}) + \bar{\alpha}_{\mathrm{S}}^2(\sigma_e^{(2)} - \sigma_r^{(2)})\Sigma(x, Q^2, F)$$

- This is M_2 matching. Σ term makes cross-section tend to 0 as $F \to 0$.
- Here, M_2 modified matching is used. Modification controls behaviour at the upper limit ${F_m}^{ax}$.

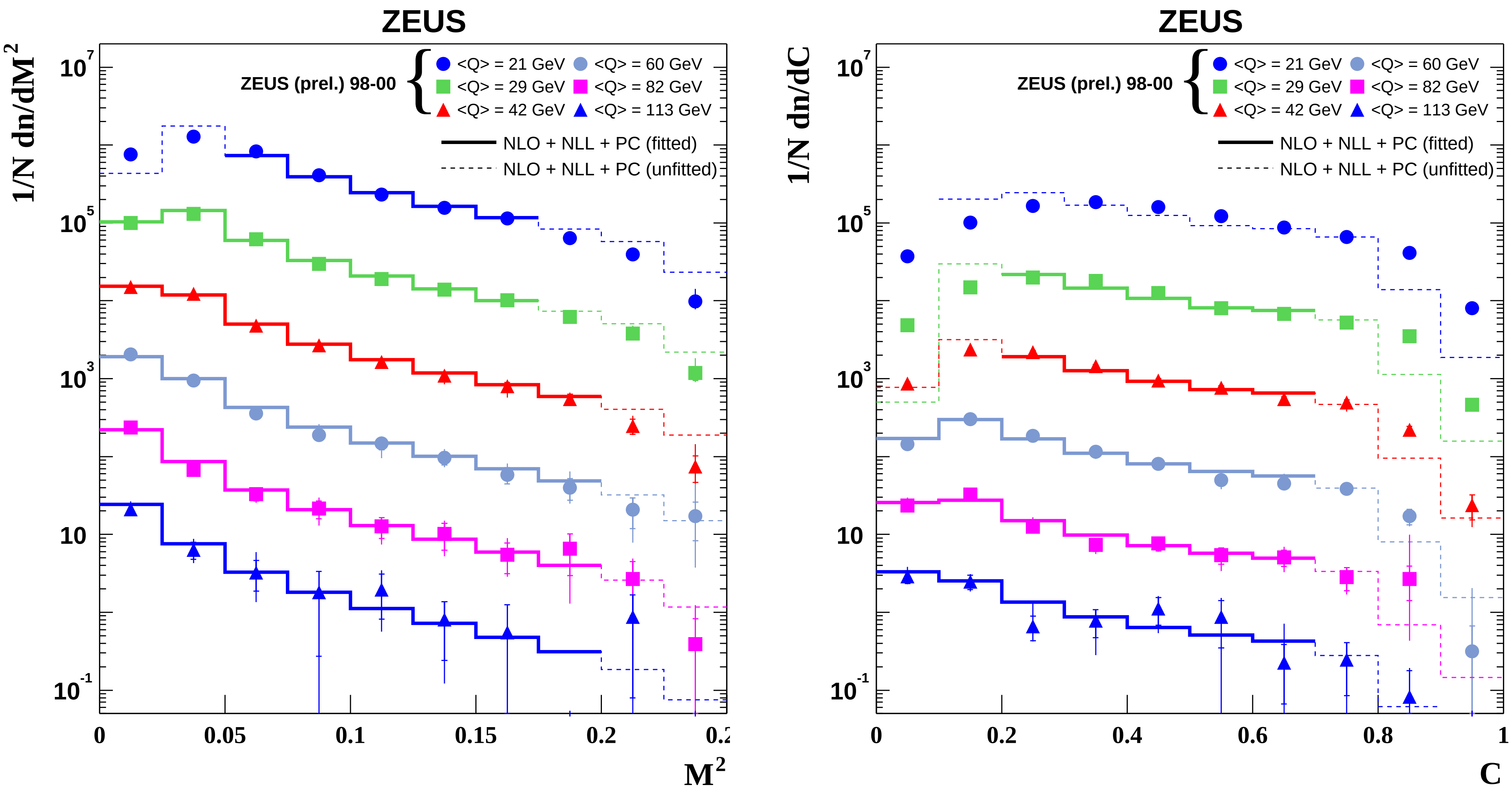
NLL + NLO + PC Fits to Differential Distributions





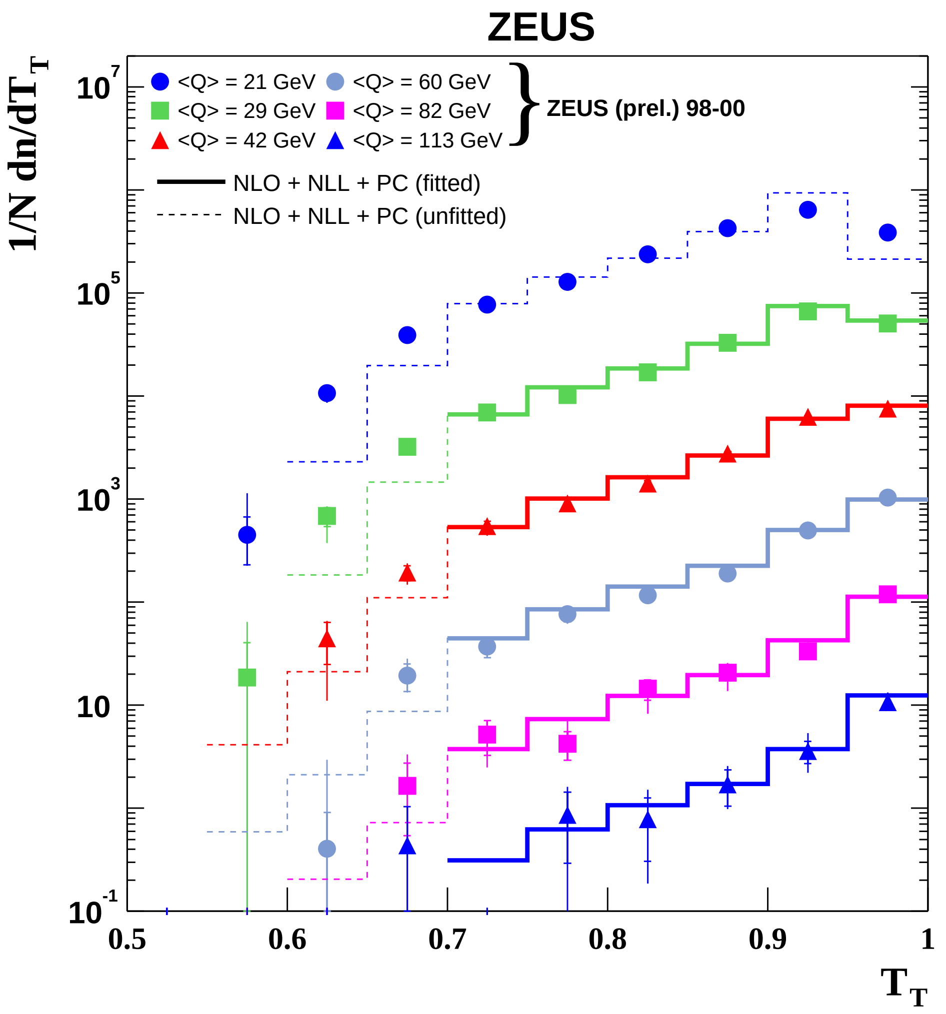
- Add NLL Resummations to fits of differential distributions - fit into peak region.

NLL + NLO + PC Fits to Differential Distributions



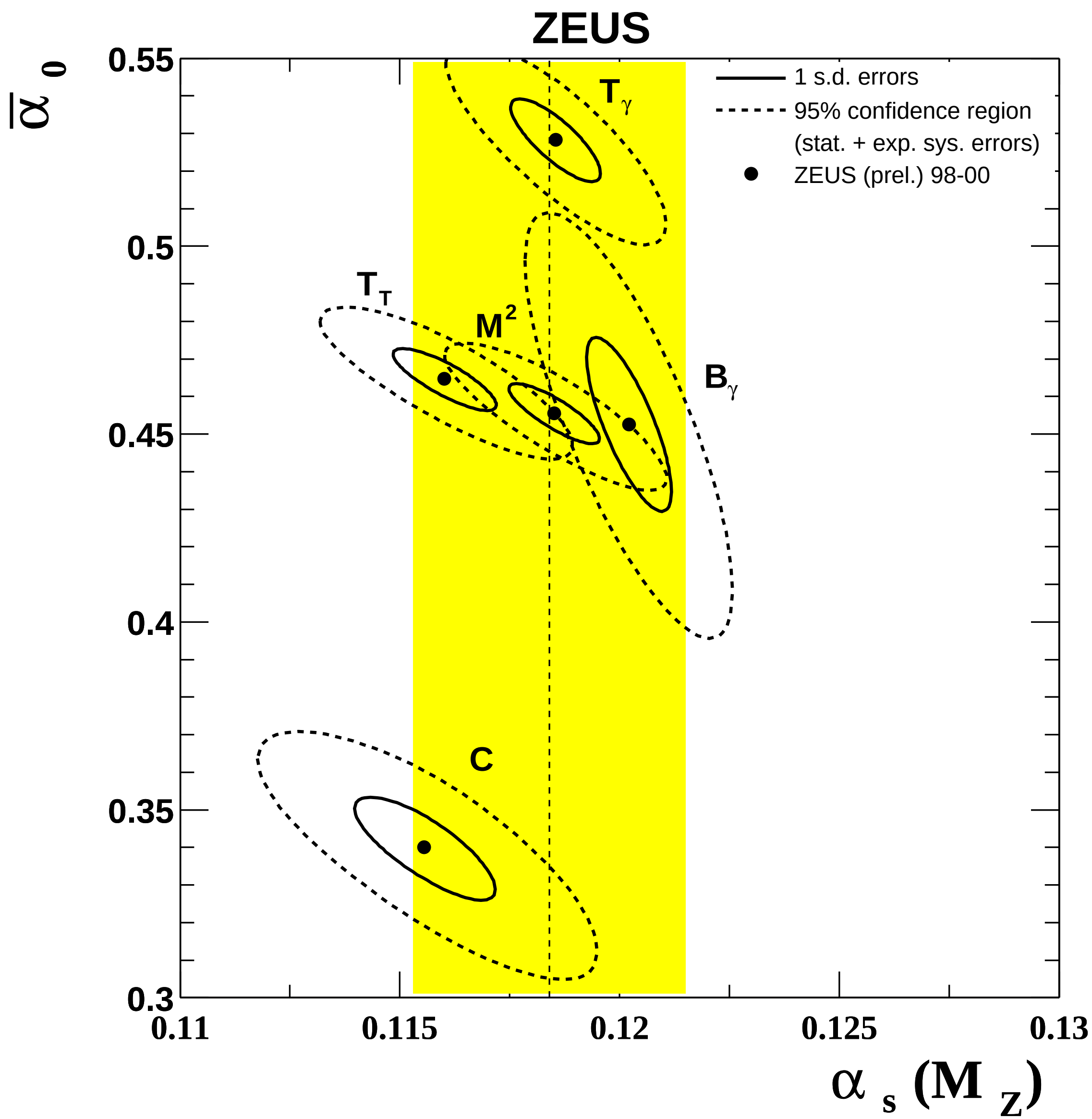
- Peaks of M^2 and C distributions now fitted.

NLL + NLO +PC Fits to Differential Distributions



- NLL resummations added to event shape fits.
- Increase in usable range - fit into peak region where resummations dominate over fixed order contribution.
- Most variables fitted with a reasonable χ^2, C is poorer.
- DISRESUM package used to perform fits.

NLL + NLO + PC Fits to Differential Distributions



- C is consistent in α_s but low in $\overline{\alpha}_0$. C result very sensitive to fitted range.
- Results consistent with $\alpha_s = 0.118$ and suggest $\overline{\alpha}_0 \simeq 0.5$.
- Fits are sensitive to matching method.
- Dominant theory errors are renormalisation scale and factor in log terms: ± 0.005 in α_s and ± 0.03 in $\overline{\alpha}_0$ each.

Conclusions

- NLO $+$ Power Correction has been fitted to mean event shape data — $\alpha_s \simeq 0.12$, $\overline{\alpha}_0 \simeq 0.45$. Consistent with published analysis.
  - Photon axis variables poorly determined.
- NLO $+$ Power Correction fitted to differential event shape data — similar α_s obtained, but $\overline{\alpha}_0 \simeq 0.65$
  - Photon axis variables not consistent with others.
- NLL Resummed calculations have been added to the fits — $\alpha_s \simeq 0.118$, $\overline{\alpha}_0 \simeq 0.5$
  - Resummation gives consistent α_s, $\overline{\alpha}_0$ for T_γ, B_γ, M^2, T_T.
  - C fit very dependent on fitted range.