dasGUPTA

POWER CORRECTIONS IN DIS EVENT SHAPES

work with Bryan Webber

1. Motivations
2. Introduction to DIS event shapes
3. Power corrections and the Dispersive approach.
4. Results
5. Conclusions.

HERA data – V rich source for α_s extraction.

In a single experiment and at a single beam energy – very wide Q^2 rang (upto 10^5 $(GeV)^2$).

V useful for α_s extraction as well as testing running coupling and hence QCD.

Observables should be chosen with care. Should have both perturbative estimates as well as dominant non-perturbative effects (i.e must understood. Understand power corrections) understood.

For e^+e^- event shapes power corrections understood (within certain models). $\frac{1}{Q}$ effect seen.

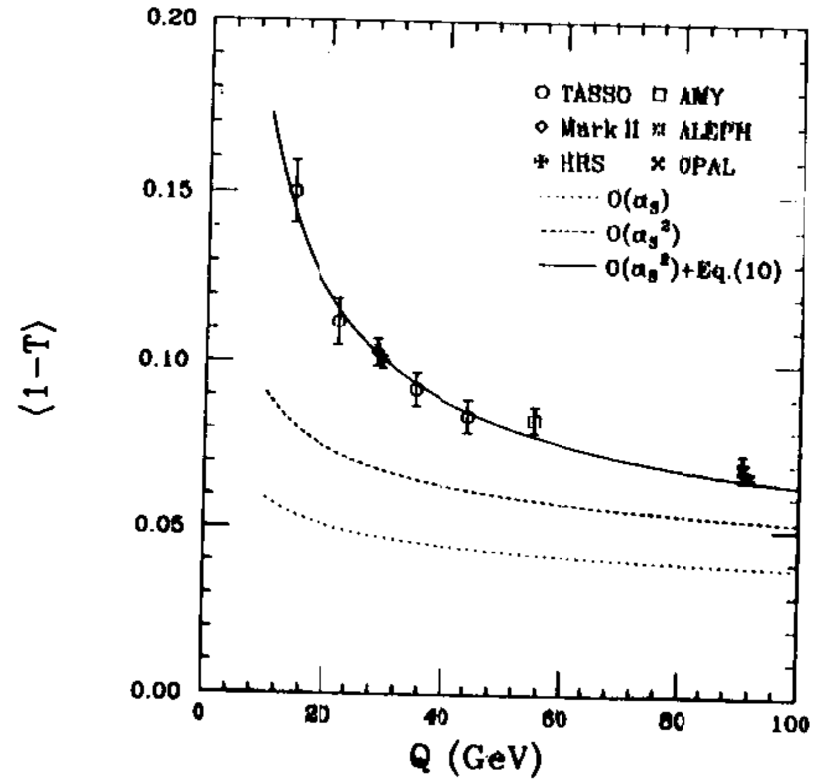


Figure 1: Mean value of $1 - T$, where T is the thrust.

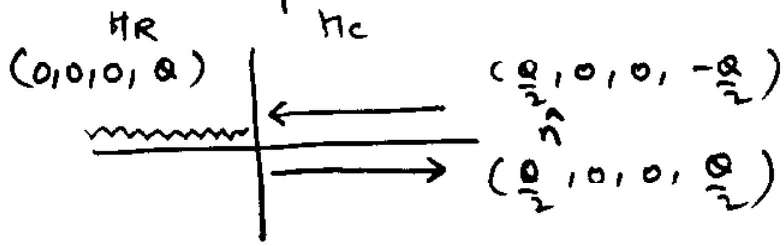
Guided by this we study power corrections in DIS Event Shapes.

Do find $\frac{1}{Q}$ corrections.

2. EVENT SHAPES IN DIS

Use Breit frame of reference.

Here's a picture.



(parton model)

Virtual photon has a space-like 4 momentum oriented along our 3 axis (current axis).

Struck quark bounces back into $\mathcal{H}_R$.

Remnant carries on.

Remnant not useful for α_s extraction

We look only at $\mathcal{H}_C$.

Also current jet looks like one half of an e^+e^- event.

Use the above facts as motivations in defining current jet event shapes in DIS.

I By analogy with e e - possible to construct Infrared safe Shape variables (linear sums of momenta)

1. Current jet thrust - T^Q

$$= \frac{2}{Q} \sum_{a \in H_c} |\vec{p}_a \cdot \vec{n}|$$

deviations from unity tell us of longitudinal development of jet.

($\underline{n}$ is boson (current) axis)

2. Current jet broadening

$$B^Q = \frac{1}{Q} \sum_{a \in H_c} |\vec{p}_a \times \vec{n}|$$

- transverse development of jet.

3. Current jet mass

$$\rho^Q = \left[\sum_{a \in H_c} (p_a)\right]^2 / Q^2$$

4. C parameter

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

λ's are eigenvalues of

$$\Theta^{ij} = \frac{2}{Q} \sum_a \frac{p_a^i \, p_a^j}{|p_a|}$$

linearized momentum tensor.

3. Power Corrections

Use dispersive approach of DOKSHITZER, MARCHESINI, WEBBER (CERN-TH/95-281 hep-ph/9512336

Involves writing down a dispersion relation for the coupling as exists in QED.

$$\alpha_s(k^2) = -\int_0^\infty \frac{d\mu^2}{\mu^2+k^2}\,\rho_s(\mu^2)$$

- assumes infra-red finite coupling value differs from perturbative below some IR matching scale - μ_I.

Also assume that this infra-red behaviour is UNIVERSAL.

Phenomenological success of approach rests on this assumption.

Approach also provides a systematic framework for the inclusion of a gluon mass in perturbative calculations - exactly equivalent to estimating the renormalon ambiguity.

This method allows us to write the power correction to an observable F in the form

$$F^{pow} = \int_0^\infty \frac{d\mu^2}{\mu^2}\, \delta\alpha_{eff}(\mu^2)\, \dot{F}\left(\{x\},\, \epsilon = \frac{\mu^2}{Q^2}\right)$$

Here F is the first order correction to the observable but computed with a finite gluon mass μ^2. We work with dimensionless $\epsilon = \mu^2/Q^2$.

Once this is done calculate log derivative w.r.t ϵ

$$-\epsilon \frac{\partial}{\partial \epsilon} F(\{x\}, \epsilon) = \dot{F}.$$

Insert the small ϵ limit of $\dot{F}$ into the integral. Only nonanalytic terms should survive $\rightarrow$ read by OPE.

Eg in e^+e^- we have (for ε shapes only!)

$$\dot{F} = k\sqrt{\epsilon} + O(\epsilon)$$

find

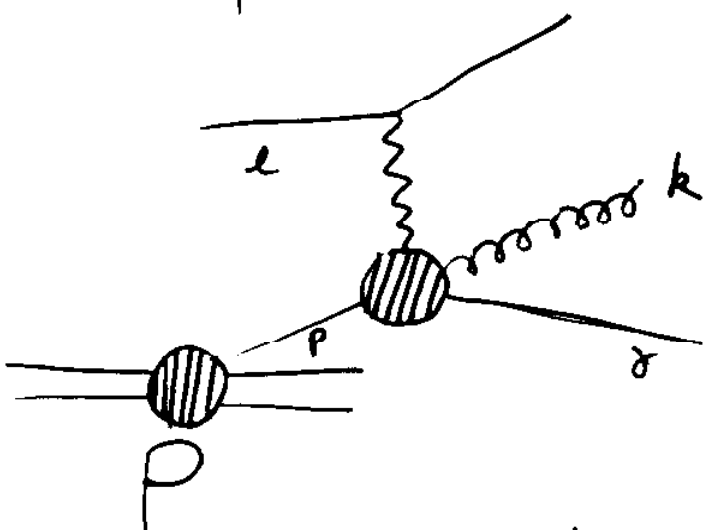
$$F^{pow} = \frac{k}{Q} \cdot \int_0^\infty \frac{d\mu^2}{\mu^2}\, \delta\alpha_{eff}(\mu^2) \cdot \mu .$$

$\ln A_1 / n$

H1 - universal (hopefully?). [illegible]
data consistent with a value
of $A_1 = 0.25$ GeV

4. Calculations and Results

Need $O(\alpha_s)$ calculations - look
at process



Also introduce phase space variables
ξ and z

$$\xi = \frac{Q^2}{2(p\cdot q)} \qquad z = 1 - \frac{(p\cdot k)}{(p\cdot q)}$$

z $0 \to 1$

ξ $x_B \to 1/1+e$

$$x_B = \frac{Q^2}{2(P\cdot q)}$$

We can then distinguish 4
distinct regions of phase space

1 Region A has both partons in HC - 1
" B has only quark in HC
" D " " gluon in HC
" D " nothing in HC.

For characteristic function for mean value of a shape S we have

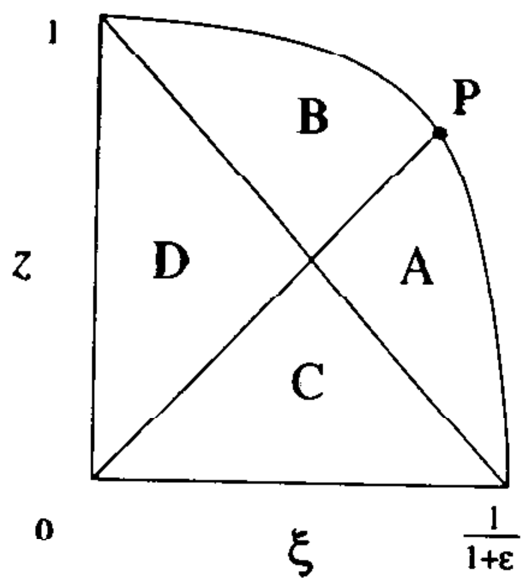


Figure 3: The phase space diagram for DIS

$$\dot{F}^{\langle s\rangle} = -\epsilon \frac{\partial}{\partial \epsilon} \int \frac{d\xi}{\xi} \int dz \; S(\xi, z, \epsilon)\; C(\xi, z)$$
$$\Theta(1 - z - \xi + \xi z - \epsilon \xi$$
$$q\left(\frac{x}{\xi}\right)$$

Also we expect power corrections to come from soft gluon boundary - pt. P

1 We adopt 2 procedures - 1

treat as

$$-\epsilon \frac{\partial}{\partial \epsilon} \int \frac{d\xi}{\xi} \int dz \; S(\xi, z, 0) \; C(\xi, z, 0) \; \Theta(1 - z - \xi + \xi z - \epsilon\xi) \; q\left(\frac{x}{\xi}\right)$$

i.e neglect order ϵ terms in C and S - corresponds to Integrating along boundary

or retain mass dependence. - much harder.

Also event shapes assume different values in different regions of phase space.

With the thrust and jet mass both ideas give same result. however, For C and B we get right behaviour though we get the wrong (incomplete) coefficient → along boundary.

Note that these variables are sensitive to $z_\perp$.

Z_3 - LONGITUDINAL MOMENTUM FRACTION OF QUARK

$\bar{Z}_3$ - LONGITUDINAL MOMENTUM FRACTION OF GLUON

$Z_\perp$ - TRANSVERSE MOMENTUM FRACTION OF QUARK.

Table 1: Event shape variables $S(\xi, z)$ in leading order.

S	A	B	C
τ_Q	$(1-\xi)/\xi$	$1-z_3$	$1-\bar{z}_3$
τ_E	$2(1-\xi)$	$1-z_3/z_0$	$1-\bar{z}_3/\bar{z}_0$
B_Q	$z_\perp$	$z_\perp/2$	$z_\perp/2$
B_E	$\xi z_\perp$	$z_\perp/2z_0$	$z_\perp/2\bar{z}_0$
ρ_Q	$(1-\xi)/\xi$	0	0
ρ_E	$\xi(1-\xi)$	0	0
C_Q	$3(2\xi-1)^2 z_\perp^2/\xi^2 z_0 \bar{z}_0$	0	0
C_E	$3(2\xi-1)^2 z_\perp^2/z_0 \bar{z}_0$	0	0

Z_0 ENERGY FRACTION OF QUARK

$\bar{Z}_0$ ENERGY FRACTION OF GLUON

$z_\perp$ actually vanishes on the boundary when full mass dependence is retained.

Massless M.E can still be retained

$$C = \frac{\xi^2 + z^2}{(1-\xi)(1-z)} + 6\xi z + 2$$

Diagrams with initial state gluons (photon gluon fusion) do not give power corrections.

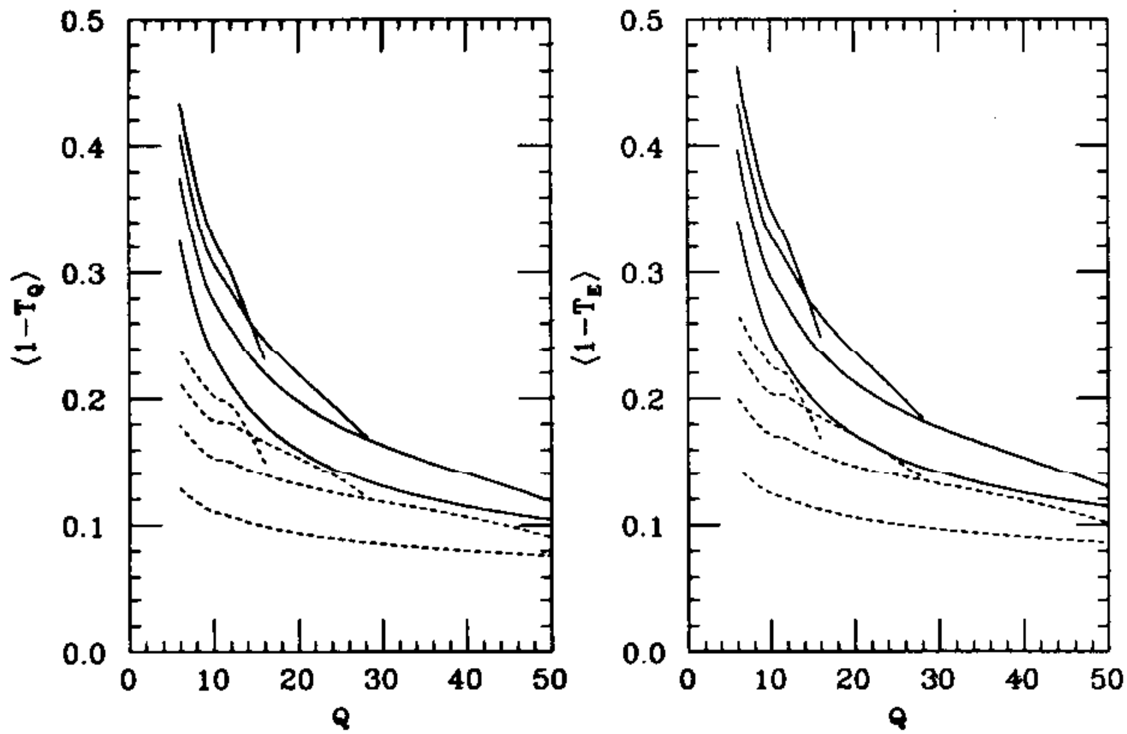
CURRENT JET THRUST

NEED ONLY INTEGRAL ALONG BOUNDARY.

$$F^T(x,\epsilon) \sim F_T(x,0) - 8\sqrt{\epsilon}\, q(x)$$

COMES FROM

$$\dot{F}(x,\epsilon) = \int_x^{\xi_p} \frac{d\xi}{\xi}\, \epsilon \frac{1+\xi^2}{(1-\xi)^2}\, q\left(\frac{x}{\xi}\right) + \int_{\xi_p}^{1} \frac{d\xi}{\xi} \frac{1+\xi^2}{\xi}\, q\left(\frac{x}{\xi}\right)$$



PLOT IS FOR BOTH NORMALIZATION

HERA ENERGIES $\sqrt{s} = 296$ GeV.

MRS A' PARTON DIST. USED

4 values of x $.003 \rightarrow .10$

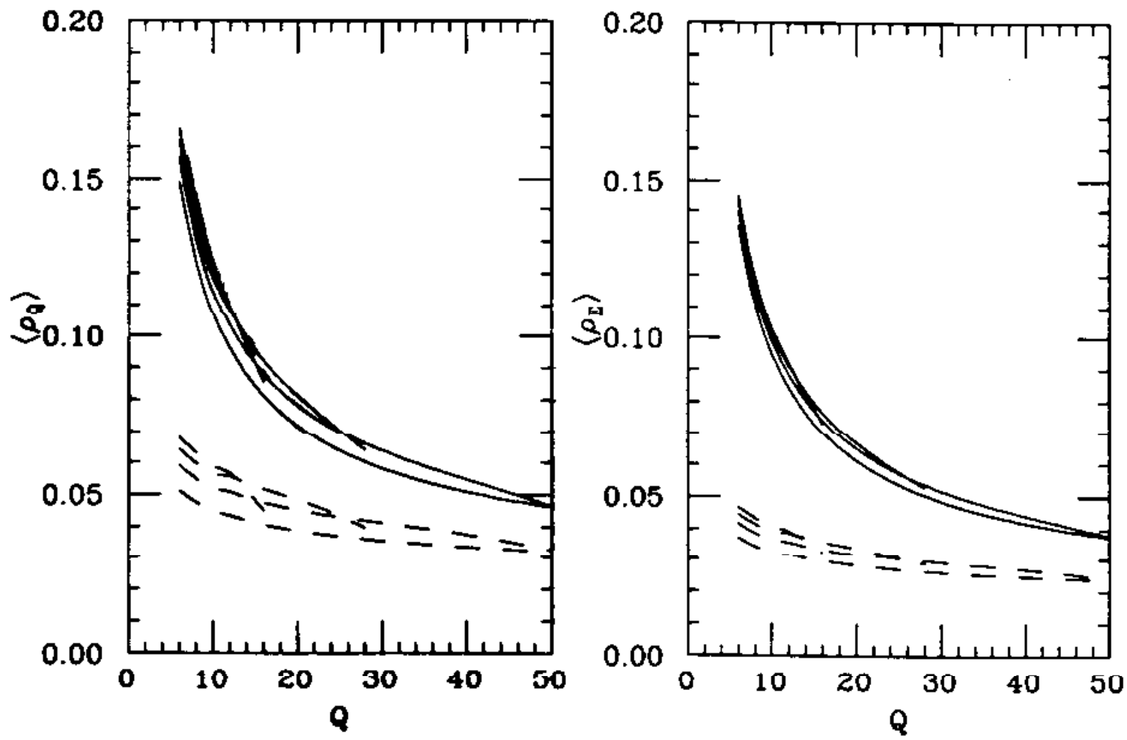
dashed curve - pert. (α_0); solid curve = α_0 + power correction.

CURRENT JET MASS

AGAIN ONLY NEED INTEGRAL ALONG SOFT BOUNDARY.

$$F(x|\epsilon) \sim F(x|0) - 4\sqrt{\epsilon}\, q(x)$$

$$\delta\langle\rho\rangle \sim \frac{2A_1}{Q}.$$



LARGER POWER CORRECTION (rel. to pert. prediction) COMPARED TO THRUST.

LESS x DEPENDENCE.

SEEMS A GOOD VARIABLE

C-PARAMETER

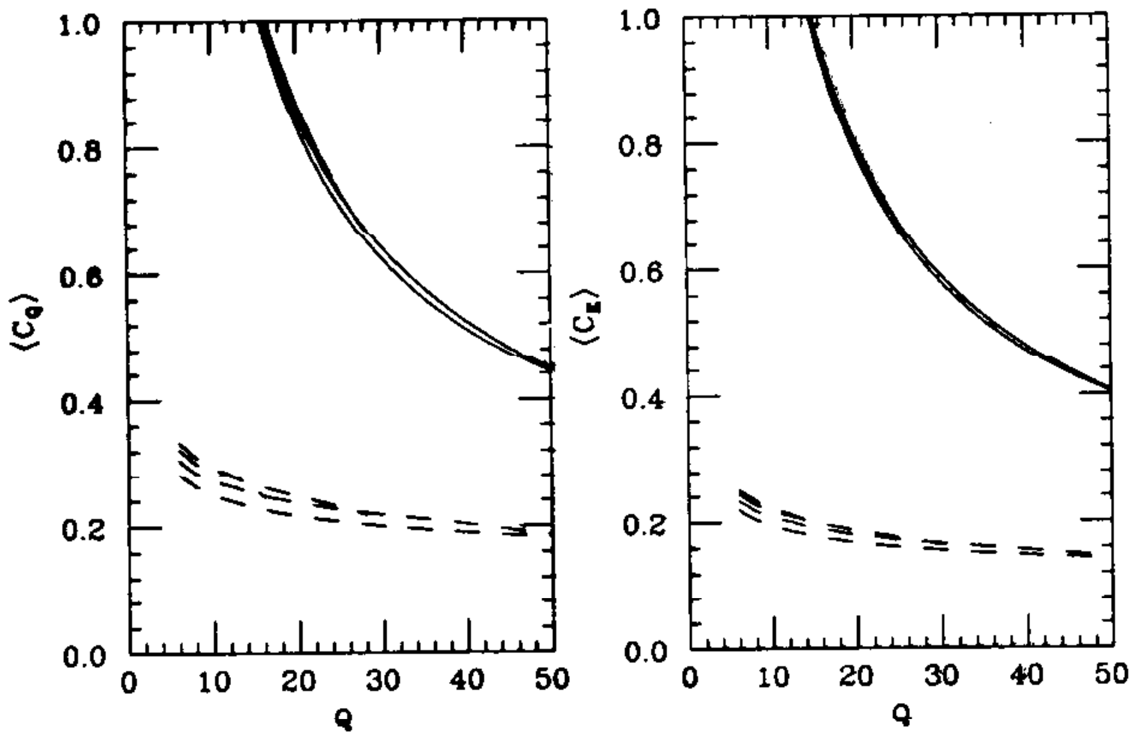
SENSITIVE TO MASS DEPENDENCE

$$F^{c}(x,\epsilon) = F^{c}(x,0) - 24\pi\sqrt{\epsilon}\, q(x)$$

$$\delta\langle c\rangle \sim 12\pi \frac{A1}{Q}$$

On boundary

$$\bar{F} \sim 12\epsilon \int \frac{\xi^2+1}{\xi^2} \frac{(2\xi-1)^2(1-\xi)}{1-\xi+\epsilon(1-2\xi)} \frac{d\xi}{(1-\xi)^2+\epsilon\xi(2\xi-1)}$$



$$\sim 6\pi\sqrt{\epsilon} \quad \text{or} \quad 6\pi\frac{A1}{Q}$$

Coefficient is halved.

Still too large.

Does not seem good for α_s

1 JET BROADENING

GET SLIGHTLY DIFFERENT BEHAVIOUR

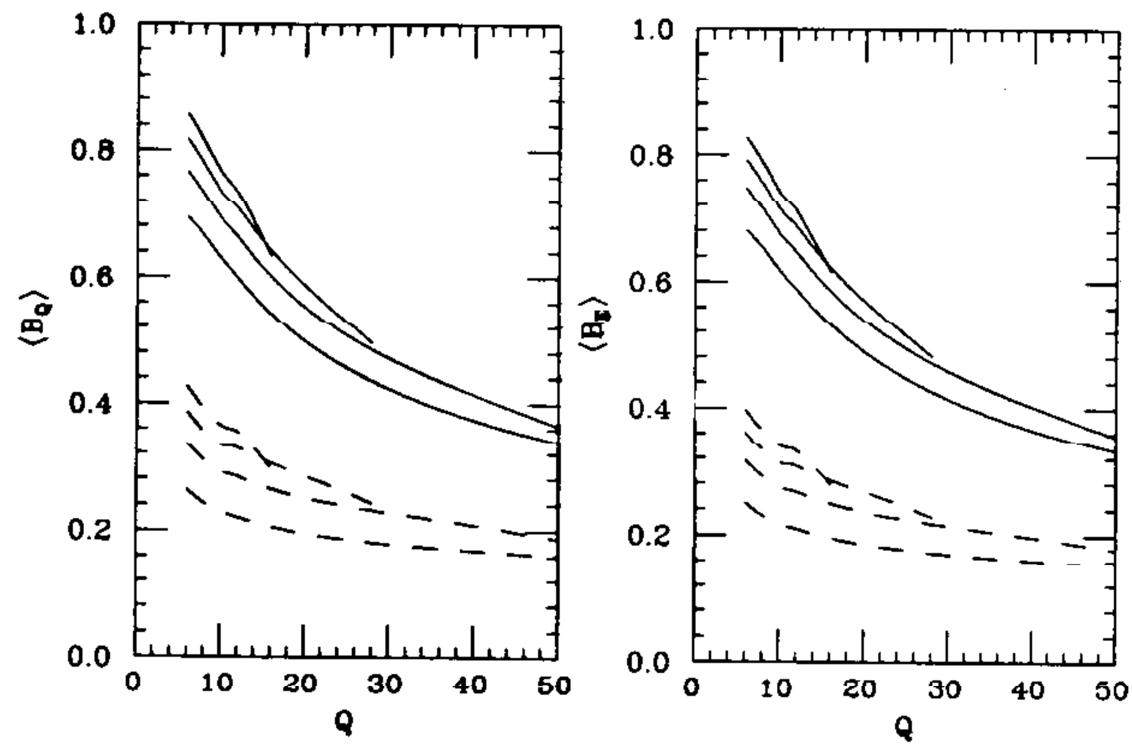
FULL (MASSIVE) CALCULATION GIVES

$$F^B(x,\epsilon) \sim F^B(x,0) + 8\sqrt{\epsilon}\,(\ln\epsilon + c)\;q(x)$$

$$\delta\langle B\rangle = \frac{8A_1}{Q}\ln\frac{Q}{Q_0} \qquad Q_0 \text{ - unknown scale}$$

Boundary approx. gives

$$F = \sqrt{\epsilon}\int_x^{\xi_p}\frac{d\xi}{1-\xi}\,\frac{\xi^2+1}{\xi}\,q\left(\frac{x}{\xi}\right) + 2\sqrt{\epsilon}\int_{\xi_p}^{1/1+\epsilon}\frac{d\xi}{1-\xi}\,\frac{\xi^2+1}{\xi}\,q\left(\frac{x}{\xi}\right)$$



LARGE POWER CORRECTIONS + UNCERTAINTY ABOUT COEFFICIENT

MEAN — NOT A GOOD VARIABLE FOR α_s EXTRACTION ?

CONCLUDING REMARK.

MASSIVE GLUON APPROACH NOT COMPLETELY CORRECT FOR EVENT SHAPES.

EVENT SHAPES LESS INCLUSIVE. MUST LOOK AT DECAY PRODUCTS OF GLUON (e.g BENEKE & BRAUN SEYMOUR/NASON)

INVOLVES CUTTING A BUBBLE IN THE RENORMALON CHAIN.

WE FEEL WHILE THIS DOES NOT AFFECT COEFFICIENTS FOR $\langle 1-T_c \rangle$ and $\langle \rho_c \rangle$ IT COULD AFFECT $\langle B \rangle$ and $\langle C \rangle$ AS THEY ARE SENSITIVE TO GLUON MASS IN THE DEFINITION.

ONE MUST ALSO ADD THE NLO CONTRIBUTIONS BEFORE A FIT TO DATA IS ATTEMPTED.

CONCLUSIONS

1. OUR WORK SHOWS $\frac{1}{Q}$ CORRECTION TO ALL EVENT SHAPES.
2. WE PREDICT THE COEFFICIENTS AND COMBINE THE L.O AND POWER CORRECTIONS
3. FIND LARGE POWER CORRECTIONS FOR BROADENING AND C.
4. WE FEEL $\langle 1-T_c \rangle$ and $\langle P_c \rangle$ CAN BE USED FOR A RELIABLE EXTRACTION OF α_s.