DIS event-shape resummations
— and spin-offs —

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Moriond QCD — March 2002

Work done in collaboration with Mrinal Dasgupta

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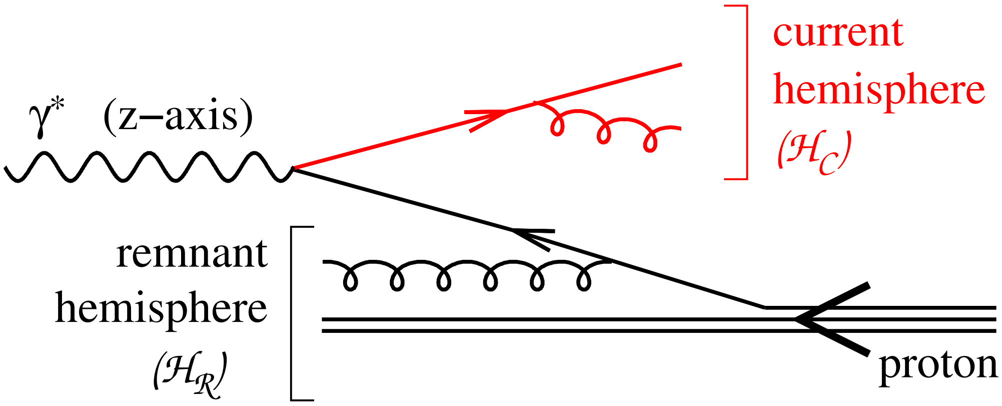
Event shapes

- ✗ Event shapes (thrust, jet mass, broadening, etc.) measure *energy flow* in an event.
- ✗ Mean values and distributions widely used in e^+e^- for measuring α_s, testing QCD, investigating non-perturbative effects.
- ✗ In DIS, mean values have been analysed, but there is also a *VAST* amount of data on distributions: *over 500 data points* from H1; ZEUS promising something similar in future.
- ✗ Theoretical comparisons to event shape distributions require *resummation* of large logs:
  - ☞ The project was started 3 years ago.
  - ☞ Simply an 'extension' of e^+e^- calculations to DIS?
  - ☞ Should have been straightforward. . .

Here's (some of) what we found on the way. . .

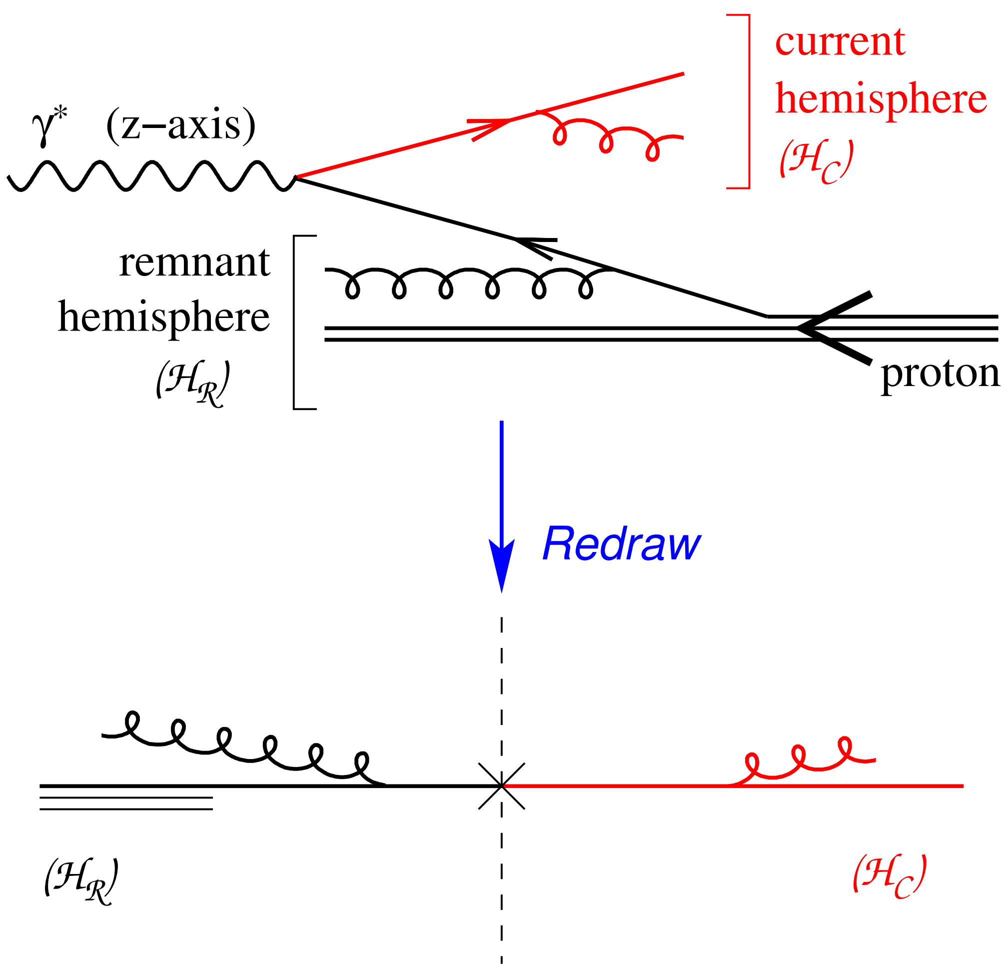
Breit frame



Define various event shapes based on particles flowing into *current hemisphere* (so as to avoid proton remnant), *e.g.*

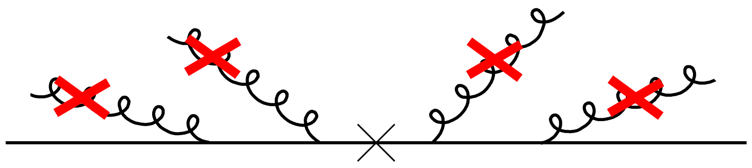
- ✗ $\tau_{zE} = 1 - \frac{1}{\mathcal{E}_\mathcal{C}} \sum_{i \in \mathcal{H}_\mathcal{C}} p_{zi}$ (thrust wrt z axis, norm. to $\mathcal{E}_\mathcal{C}$)
- ✗ $\tau_{tE} = 1 - \frac{1}{\mathcal{E}_\mathcal{C}} \max_{\vec{n}} \sum_{i \in \mathcal{H}_\mathcal{C}} |\vec{p}_i.\vec{n}|$ (thrust wrt thrust axis, . . .)
- ✗ $\rho_E = \frac{1}{4{\mathcal{E}_\mathcal{C}}^2} \left(\sum_{i \in \mathcal{H}_\mathcal{C}} p_i \right)^2$ (invariant jet mass)
- ✗ $B_{zE} = \frac{1}{\mathcal{E}_\mathcal{C}} \sum_{i \in \mathcal{H}_\mathcal{C}} p_{t_{zi}}$ (broadening wrt z axis)

Make it look (more) like e^+e^-



Need for resummation: e^+e^- case

When observable is close to Born limit ($V \ll 1$), *FORBID* all except very soft and/or collinear radiation, *e.g.* in e^+e^-:



This leads to (soft and collinear) double and single logs:

$$(\alpha_s \ln^2 V)^n\,, \qquad\qquad (\alpha_s \ln V)^m\,,$$

which need to be *resummed* $\to\sim e^{-\alpha_s \ln^2 V}$.

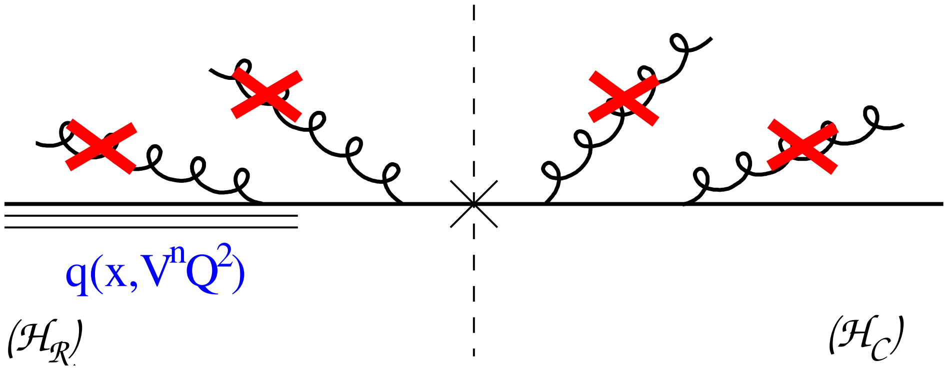
Calculation usually done assuming angular ordering, which reduces to assuming *independent primary emissions* (plus account of running coupling).

Aim to guarantee correctness of leading (double) logs and next-to-leading (single) logs.

Going from e^+e^- to DIS (1)

Two kinds of observable:

✗ GLOBAL observables are sensitive to emissions in the whole event (because of recoil). Examples are B_{zE}, τ_{zQ}.



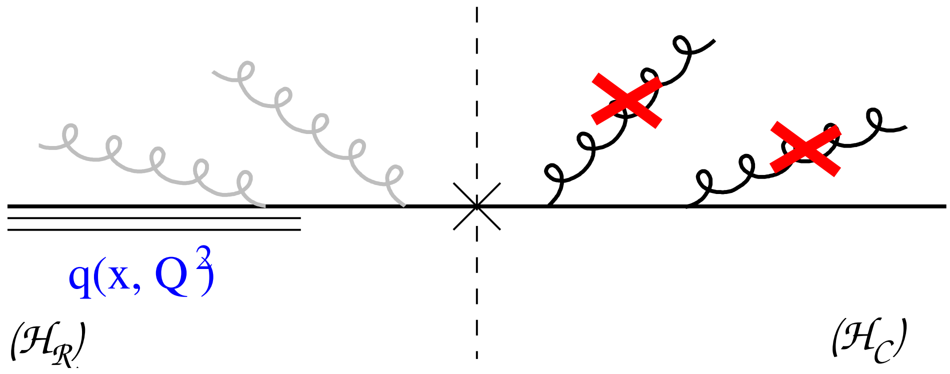
Forbidding *incoming collinear emissions* interferes with collinear factorisation. Scale of quark distribution is modified

$$q(x, Q^2) \longrightarrow q(x, V^n Q^2)$$

This extra scale dependence is the first of the DIS complications. Conceptually well understood from hadron-hadron resummations of 1980's.

Going from e^+e^- to DIS (2)

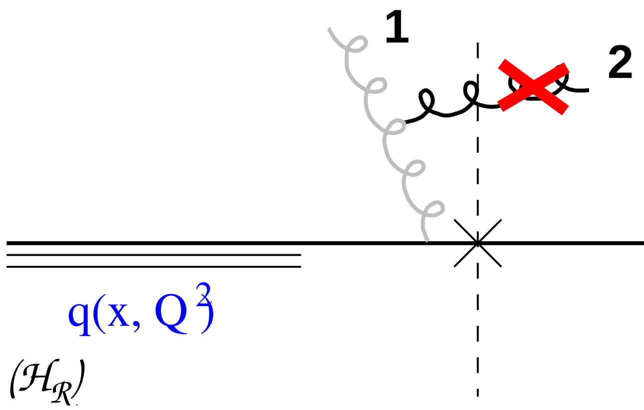
✗ NON-GLOBAL observables are sensitive to emissions in only part of the event (current hemisphere).



Approximation of *independent emissions* implies suppression only of primary emission in $\mathcal{H}_\mathcal{C}$.

This is *WRONG FOR SINGLE LOGS.* Must also

suppress energy-ordered large-angle secondary emissions:



$Q \gg E_1 \gg E_2 \gg VQ$

➥ $\alpha_s^2 \ln^2 V$

‘Non-global’ effects overlooked *many times*

G. Oderda and G. Sterman, “Energy and color flow in dijet rapidity gaps,” PRL **81** (1998) 3591 [hep-ph/9806530].

G. Oderda, “Dijet rapidity gaps in photoproduction from perturbative QCD,”
PRD **61** (2000) 014004 [hep-ph/9903240].

V. Antonelli, M. Dasgupta and G. P. Salam, “Resummation of thrust distributions in DIS,”
JHEP **02** (2001) 001 [hep-ph/9912488]. [τ_{zE}]

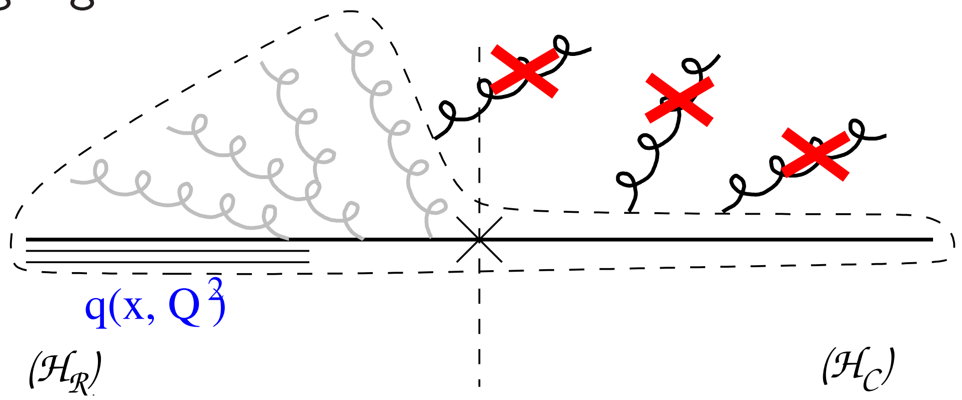
A. Banfi, G. Marchesini, Yu. L. Dokshitzer and G. Zanderighi, “QCD analysis of near-to-planar 3-jet events,” JHEP **07** (2000) 002 [hep-ph/0004027]. [$K_{\rm out}^{\rm right}$]

S. J. Burby and E. W. Glover, “Resumming the light hemisphere mass and narrow jet broadening distributions in e^+e^- annihilation,”
JHEP **04** (2001) 029 [hep-ph/0101226 v1].

C.F. Berger, T. Kúcs and G. Sterman, “Energy flow in interjet radiation” [hep-ph/0110004].

All-orders?

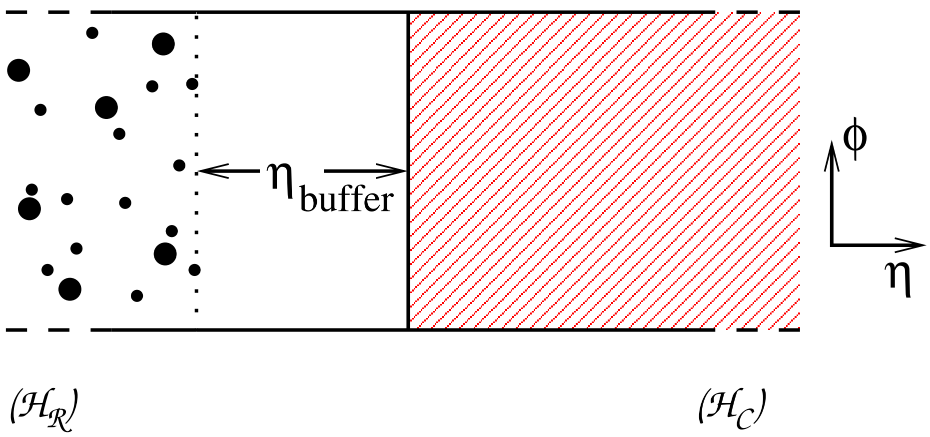
Forbid coherent radiation from energy-ordered ensembles of large-angle gluons



✗ Complex colour structure → large-N_C limit

✗ Complex 3D geometry → numerical solution

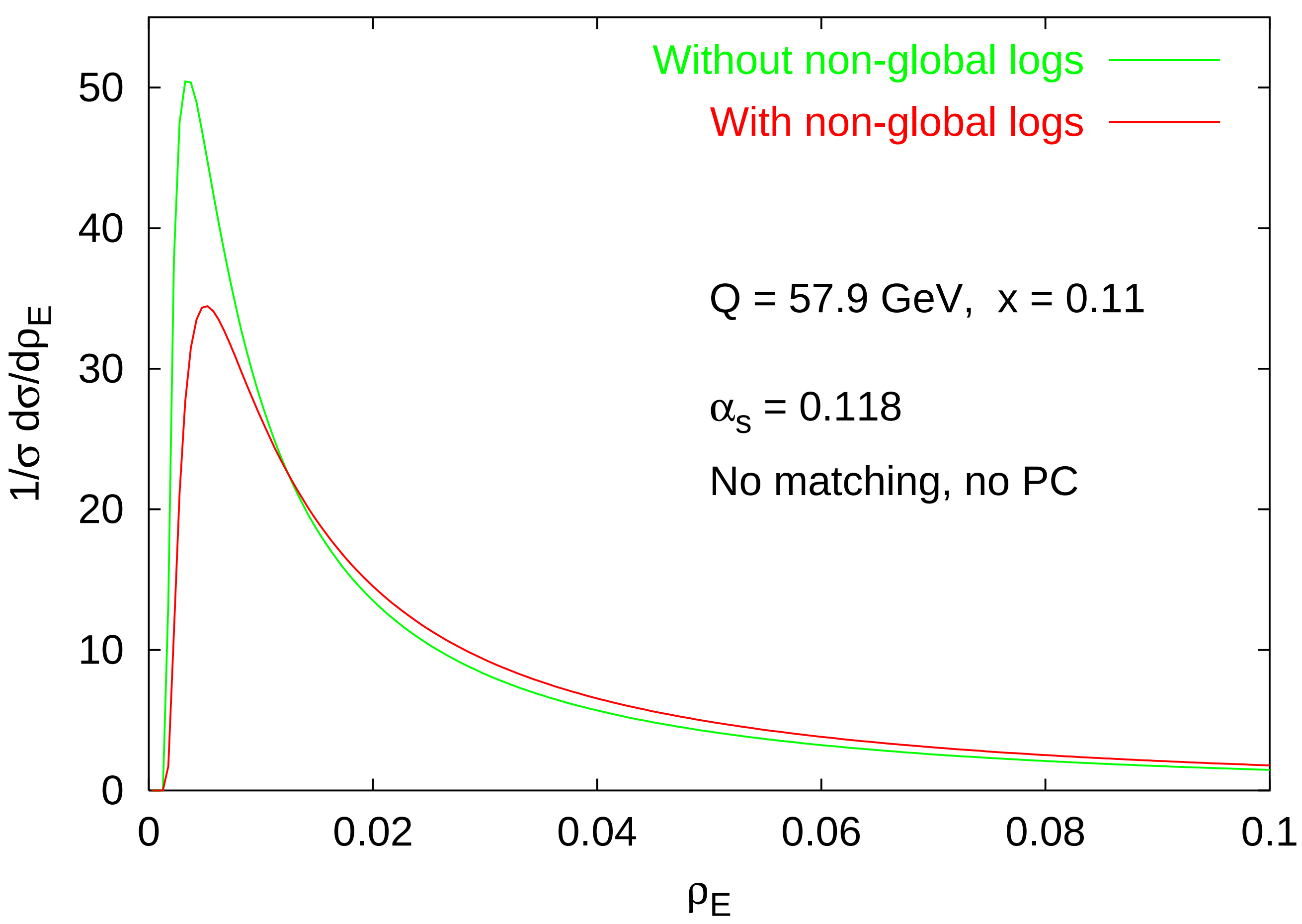
✗ Some elements understandable with simple arguments:



Phenomenological importance: DIS ρ_E

NLL resummed distribution for squared jet mass:

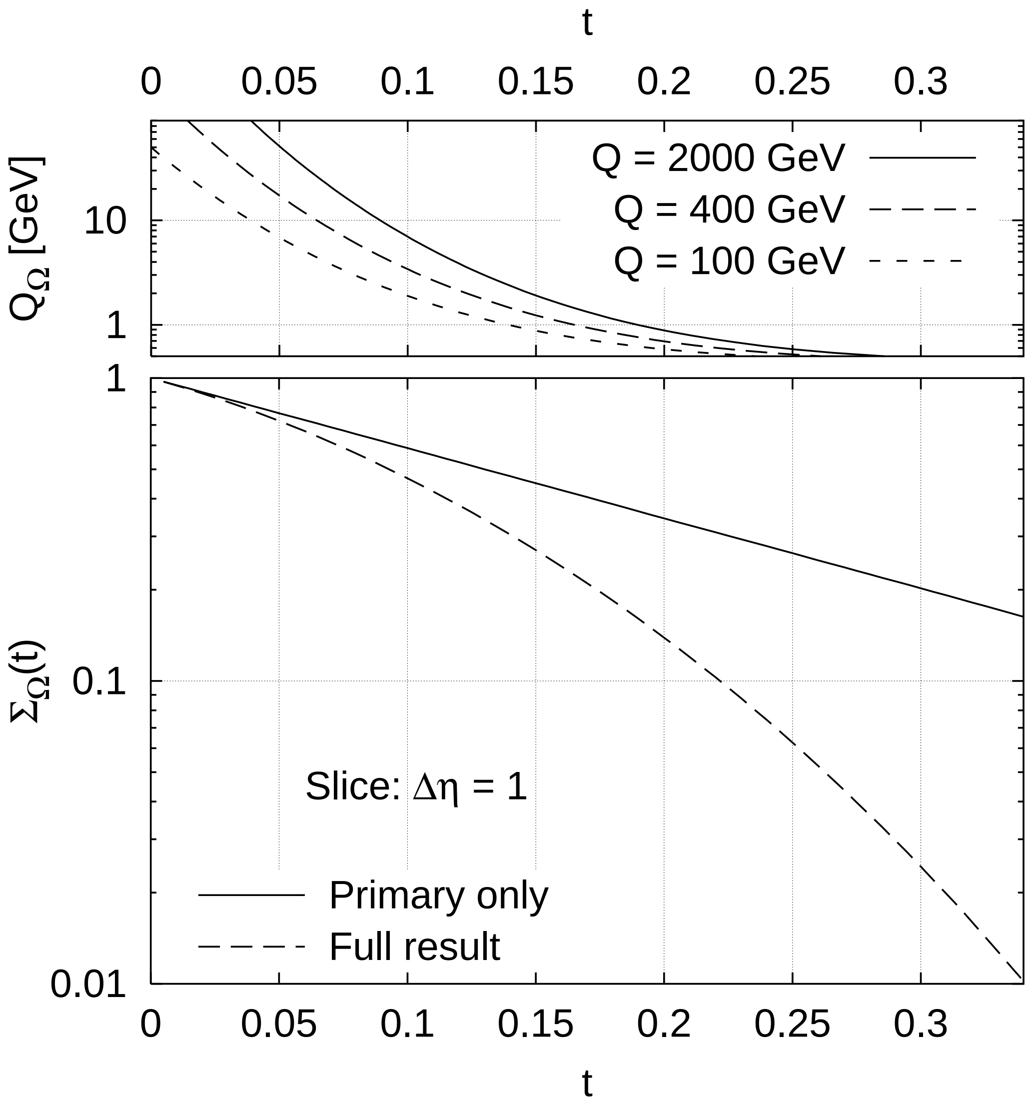
Dasgupta & GPS, hep-ph/0104277 & in preparation



Interjet energy flow & rapidity gaps

Non-global single-logs for distribution of interjet energy flow and certain rapidity gap definitions. Calculated in 2-jet case,

Dasgupta & GPS, hep-ph/0203009



Other spin offs (1)

PDF evolution code: wanted control over PDF evolution beyond what is available in tabulated MRST, CTEQ, GRV code (for smoothness, α_s dependence, . . .).

Developed our own code, with unexpected results:

- ✗ 'Discovery' of (numerical?) bug for $x < 10^{-4}$ in MRST99 evolution, at 10-15% level (reduced to 1-2% in MRST2001).

- ✗ Discovery that CTEQ5 DIS scheme used $\overline{\text{MS}}$ splitting functions (fixed in CTEQ6).

- ✗ Accurate reference (1 part in 10^5) for LO, NLO, NNLO evolution [with Andreas Vogt].

- ✗ . . .

Other spin offs (2)

A wrapper, *DISPATCH*, for DIS fixed-order Monte Carlos (DISENT and DISASTER++)

- ✗ Exploits factorisation to allow several x, Q^2 points to be studied for *each event*.

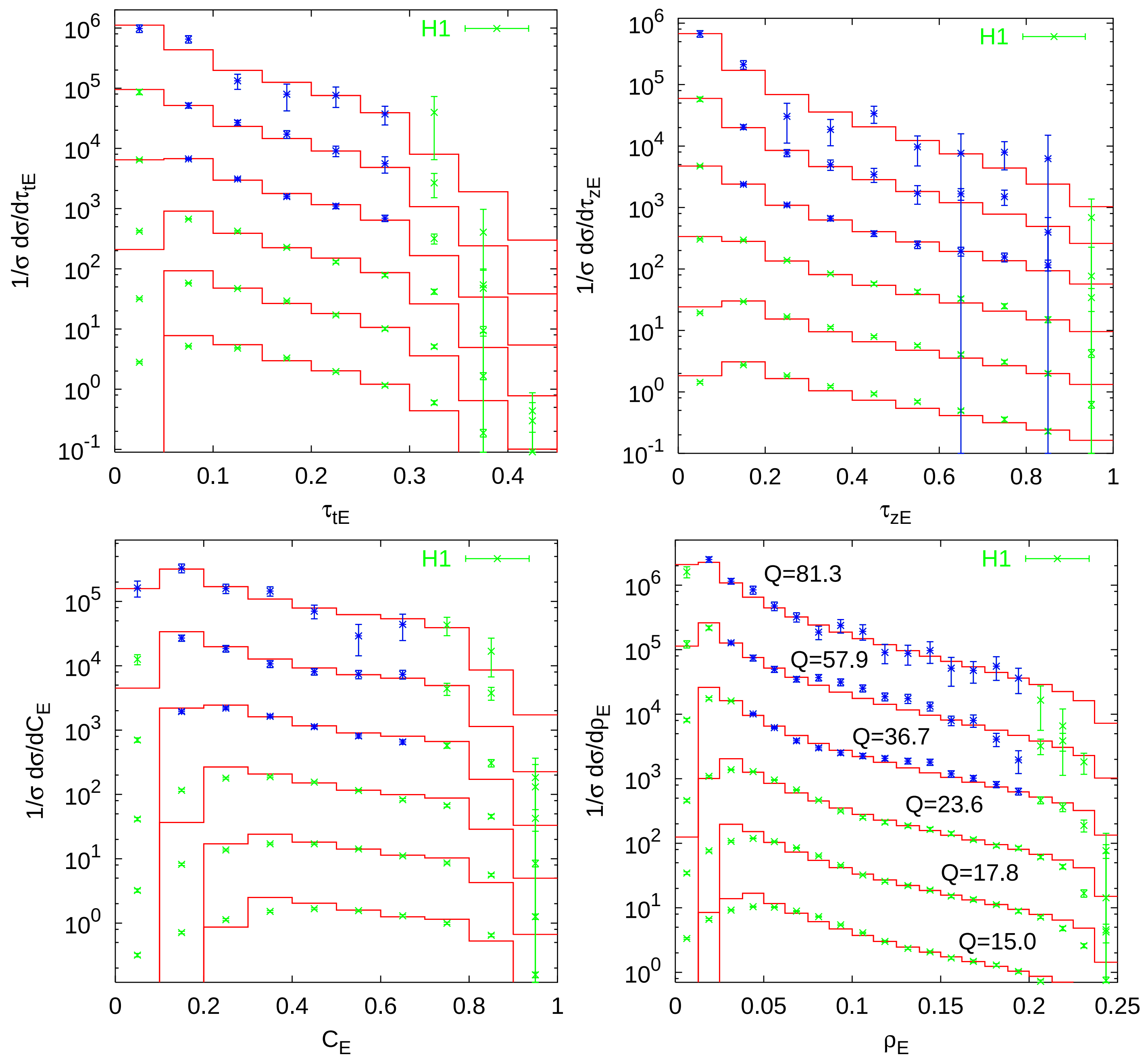
- ✗ This can give an *order of magnitude* speed improvement when many x, Q^2 points are needed (especially with DISASTER).

  - ☞ To generate fixed-order results we only needed 100 days of computing time rather than the ~ 500 days needed with default methods!

- ✗ Single 'card-file' type interface for DISENT and DISASTER++.

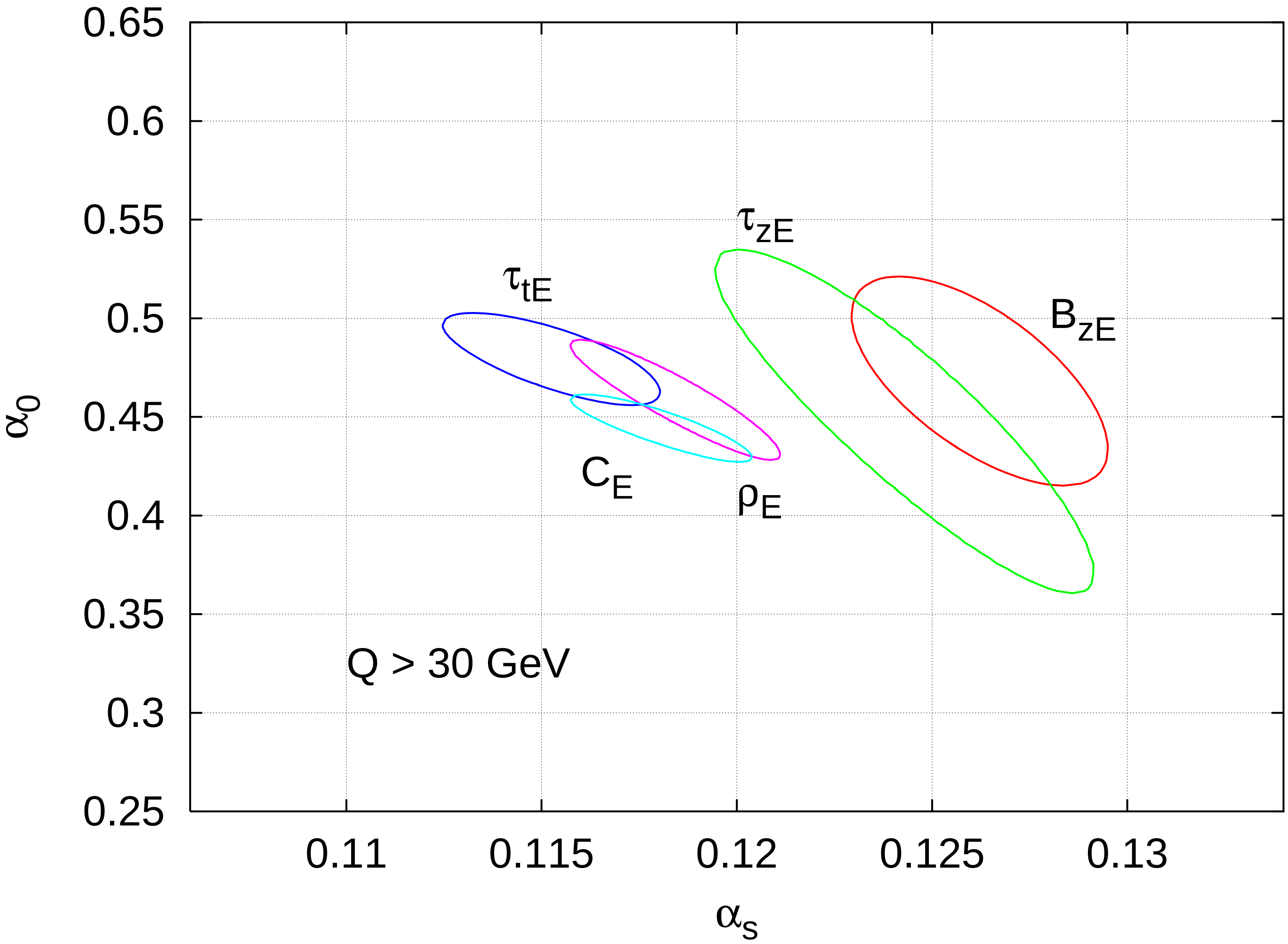
- ✗ BUT: currently restricted to event-shape like quantities.

Fits to H1 data



Results for α_s and α_0

[Non-perturbative effects are taken into account by $1/Q$ shift, determined by universal α_0 parameter]



Variables measured wrt photon (z) axis are less ‘successful’. At smaller x (and lower Q) effect becomes more dramatic.

Conclusions

Theoretical understanding and technology now exists for DIS event-shape resummations.

It involves several new theoretical & technical developments. The most important concerns non-global logs:

✗ Observables that are affected by radiation in only a limited part of phase space are *non-global*.

✗ In resummed distributions of non-global variables, there is a *new class of single log* effects: non-global logs.

✗ These have been *widely overlooked in the literature* (event shapes, rapidity gaps, energy flows).

✗ Accounting for these contributions needs a *change of philosophy:* exact angular ordering / independent emission is not sufficient.