Event Shape Update

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Outline

Progress of Event Shapes in DIS

- Similar to published paper:
  - Power Correction Model
  - Power Correction to Means
- NEW to current Glasgow and Wisconsin Analyses
  - Power Correction to Differential Distributions
  - Additional Variables
  - Direct Comparison to NLO

Approach to Non-Perturbative Calculations

pQCD prediction → measured distribution

- Correction factors for non-perturbative (soft) QCD effects

Recent theory reduces corrections for any infrared safe event shape variable, F:

Used to determine the hadronization corrections

$$\langle F \rangle = \langle F \rangle_{perturbative} + \langle F \rangle_{power\ correction}$$

$$\langle F \rangle_{pow} = a_F \frac{16}{3\pi} \frac{\mu_I}{Q} \ln^P \frac{Q}{\mu_I} \bullet \left[\overline{\alpha_0}(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\pi} \left(\ln \frac{Q}{\mu_I} + \frac{K}{\beta_0} + 1 \right) \alpha_s^2(Q) \right]$$

Power Correction

- independent of any fragmentation assumptions

$\overline{\alpha_0}$ = "non-perturbative parameter"

– (Dokshitzer, Webber, Phys. Lett. B 352(1995)451)

Variables

Old Variables

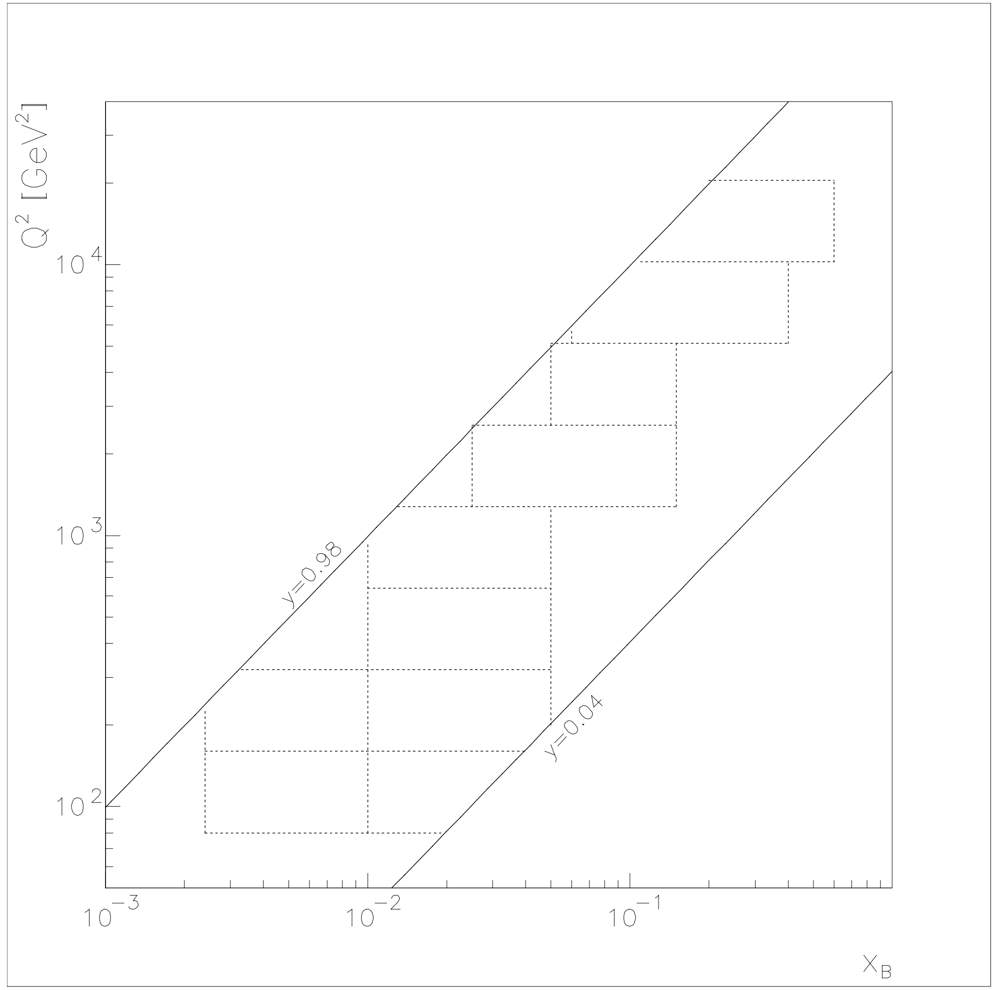
- C Parameter (infrared safe Sphericity-like variable)
- Jet Mass (axis independent)
- Thrust wrt Photon Axis (longitudinal projection)
- Broadening wrt Photon Axis (transverse projection)
- Thrust wrt Thrust Axis (longitudinal projection)
- Broadening wrt Thrust Axis (transverse projection)

New Variables

- Out-of-Plane Momentum
- Azimuthal Correlation (similar to Energy-Energy-Correlation in e^+e^-)

Kinematic Bins

- Analysis conducted in 8 bins of Q^2
- Lowest two Q^2 bins are divided into two bins of x
- Two studies:
    - Means of each variable in each bin
    - Differential distributions of each variable in each bin



Event Selection

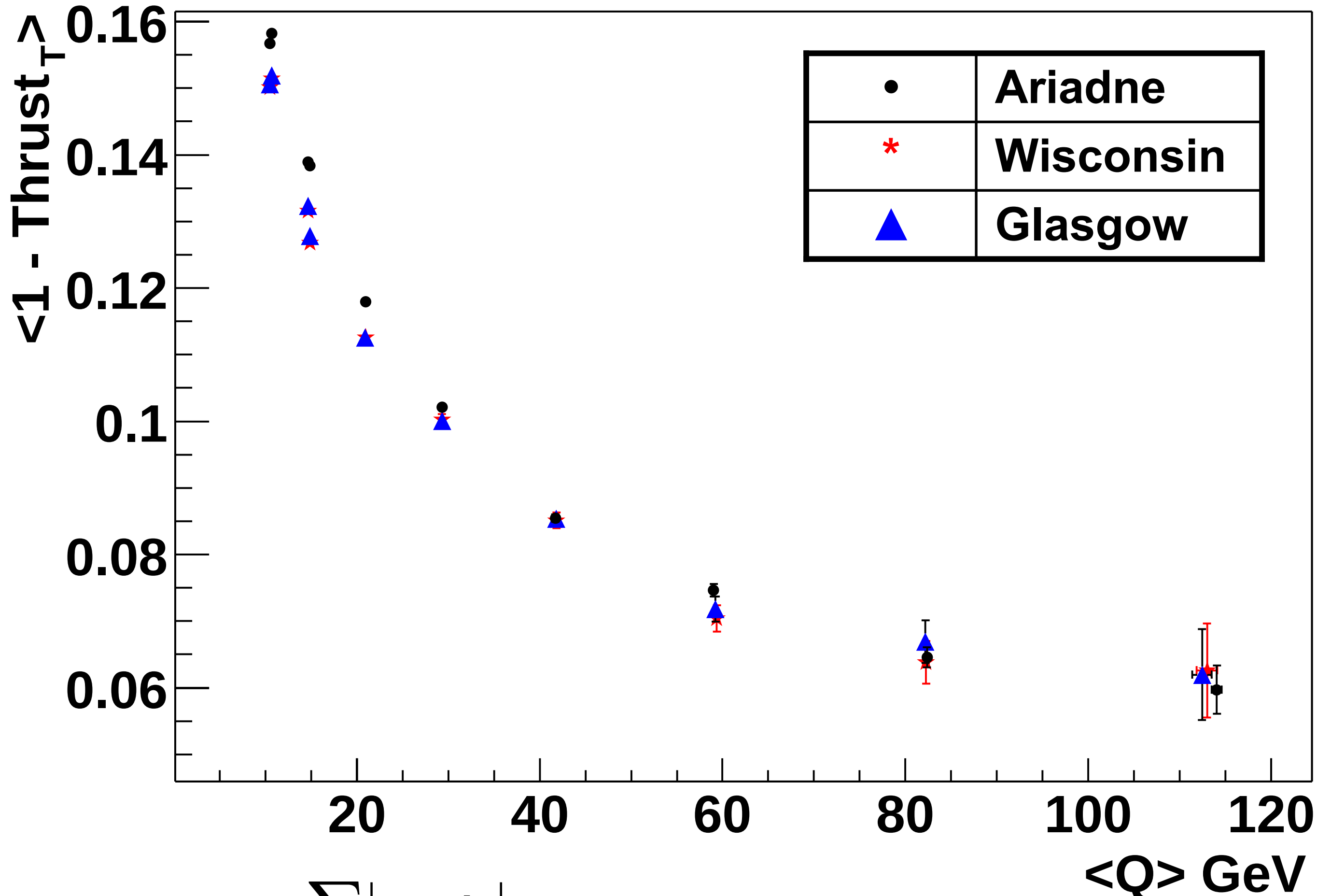
Standard DIS Selection Cuts:

- $Q^2_{EL} \geq 80$ (100) GeV^2
- $y_{JB} > 0.04$
- $y_{el} < 0.95$
- Vertex with $|z| < 40$ cm
- $38 < E\text{-}p_Z < 65$ GeV
- Good positron
  - Sinistra Probability > 0.9
  - $E_{e'} > 10$ GeV
- $|\eta|<1.75$ (2.2)
  - Temporary cut for good acceptance

Specialized Cuts:

- Analysis done in the Breit Frame
- Current Region Multiplicity ≥ 2
- At least 2 Jets in Breit Frame
  - $E_{1,T} > 6$ GeV
  - $E_{2,T} > 5$ GeV
  - $P_{T,i,Lab} \geq 2$ GeV

Complementary Analyses - Means

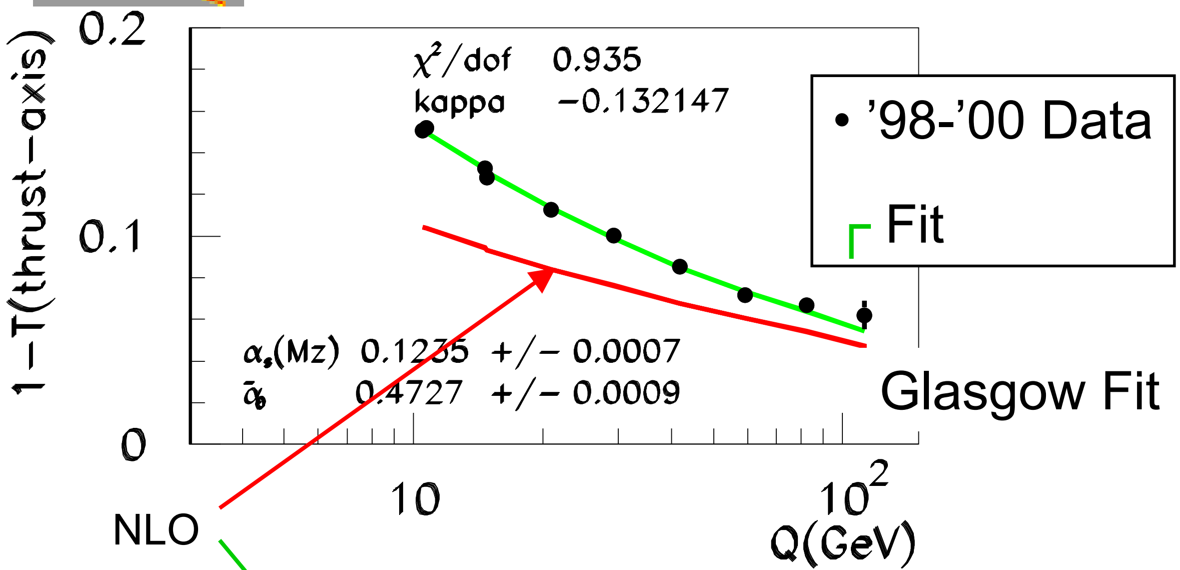


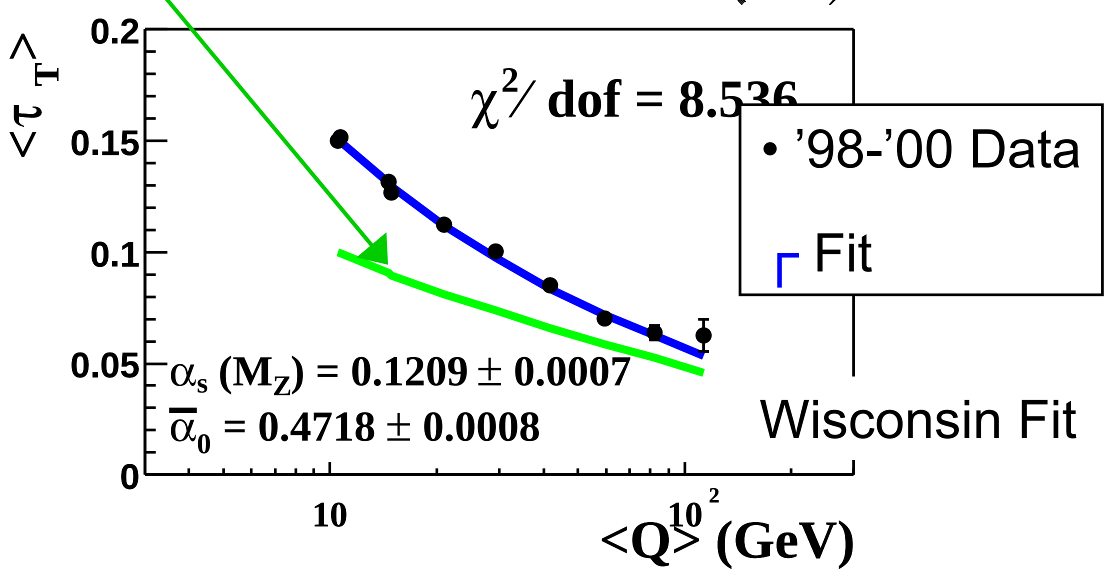
$$T_k = \max_{\hat{n}_k} \frac{\sum_i |\vec{p}_i \cdot \hat{n}_k|}{\sum_i |\vec{p}_i|}$$

Agreement for event Thrust$_T$ means between analyses

Agreement for event shape means between '96-'97 and '98-'00

Power Correction



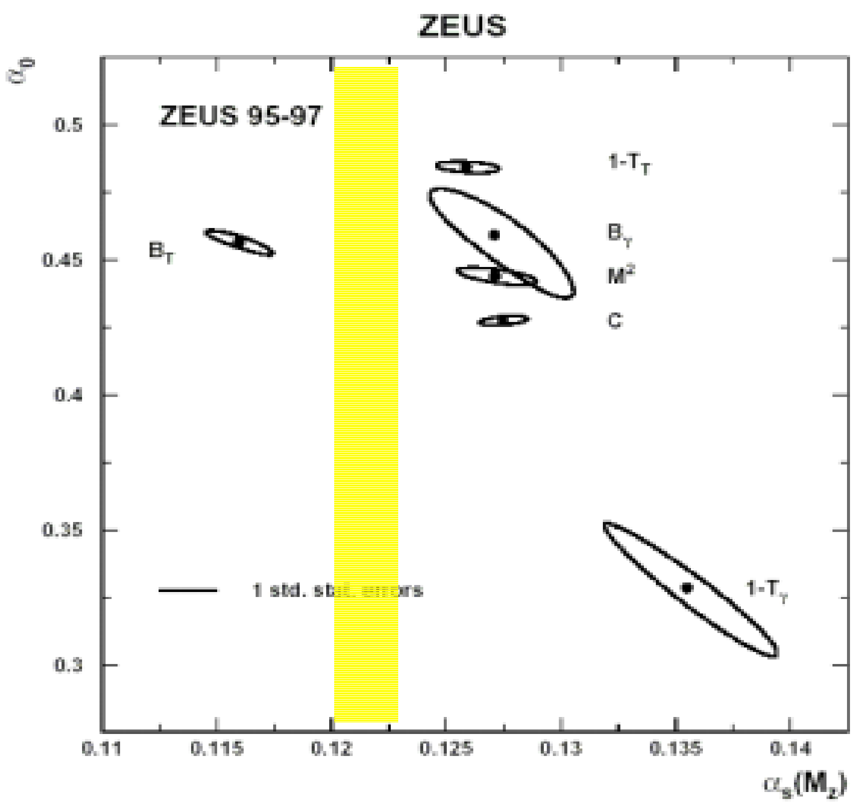


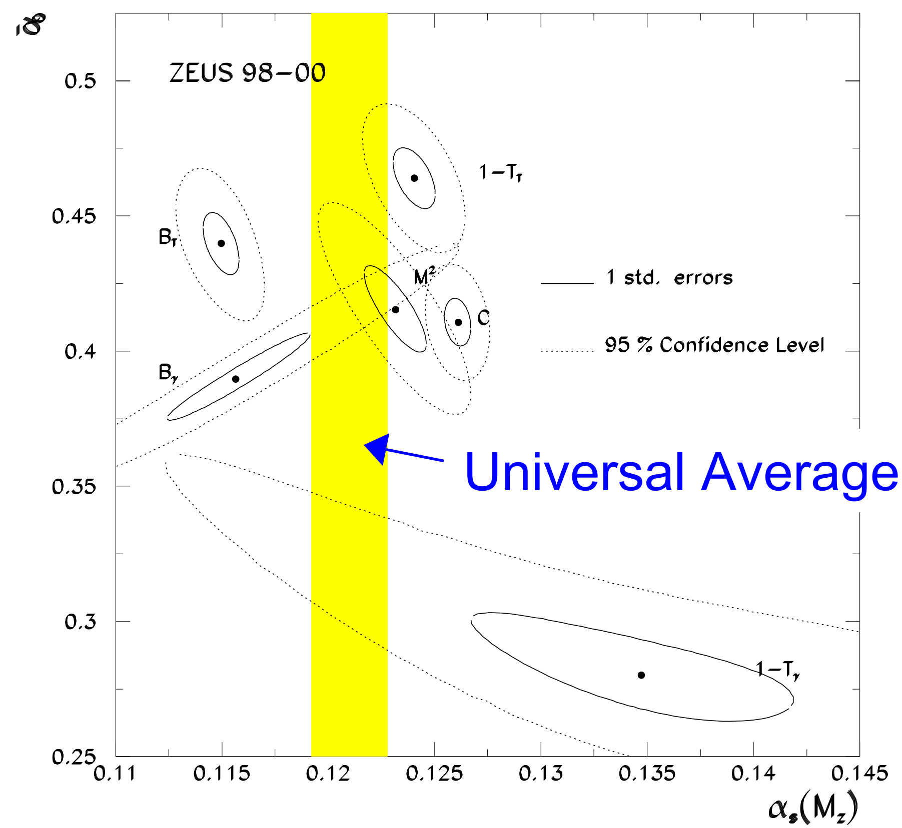
Extract α_s, α_0 :

- Value of fit ~ α_s, α_0 according to power correction equation
- Power correction can be calculated for all i.r. safe event shapes

Similar results between two analyses

Comparison With Published Results



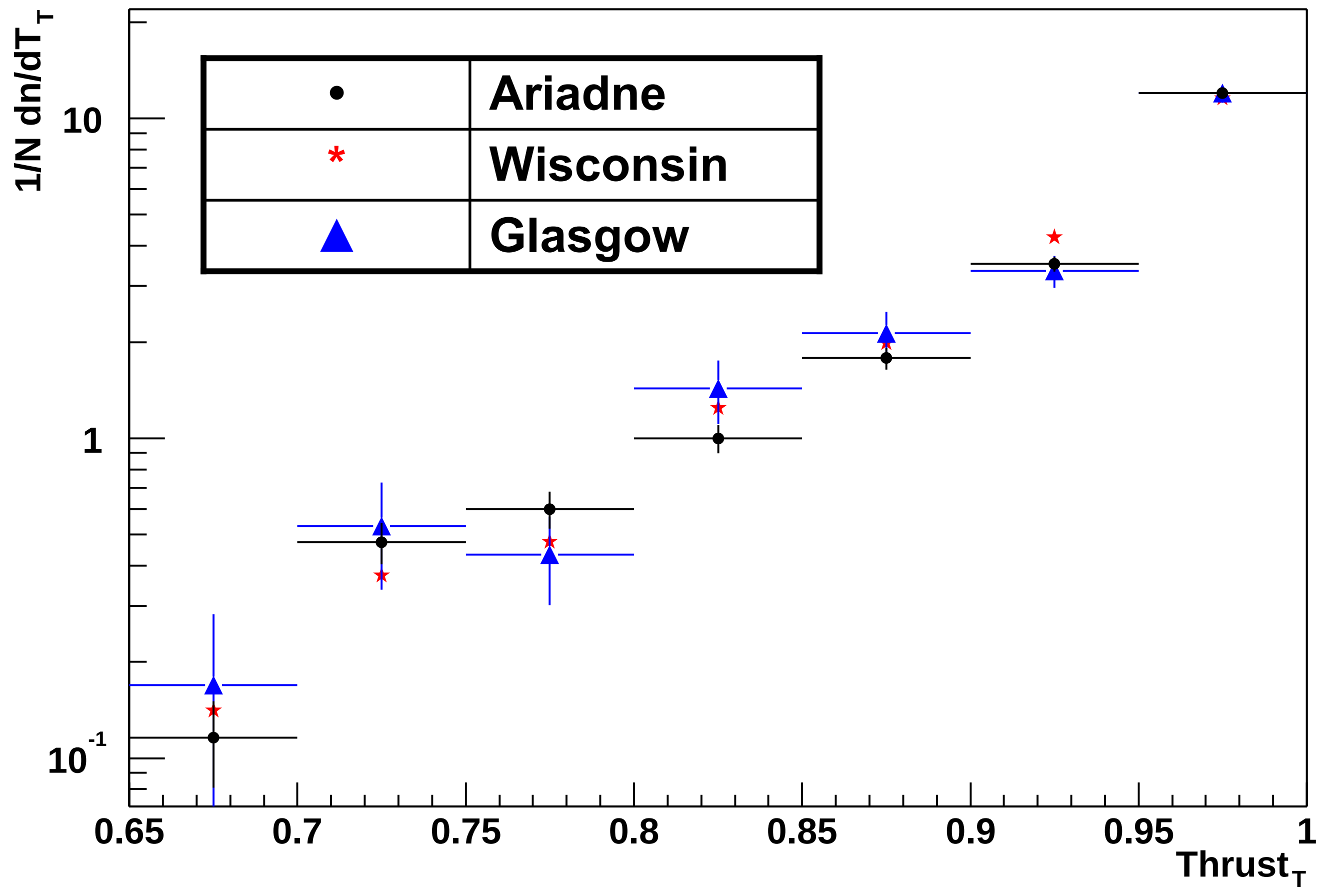


- **Results are consistent between ’96-’97 and ’98-’00**
- **Similar difficulties with variables dependent on γ* axis**

Comparison of Differential Distributions

New:

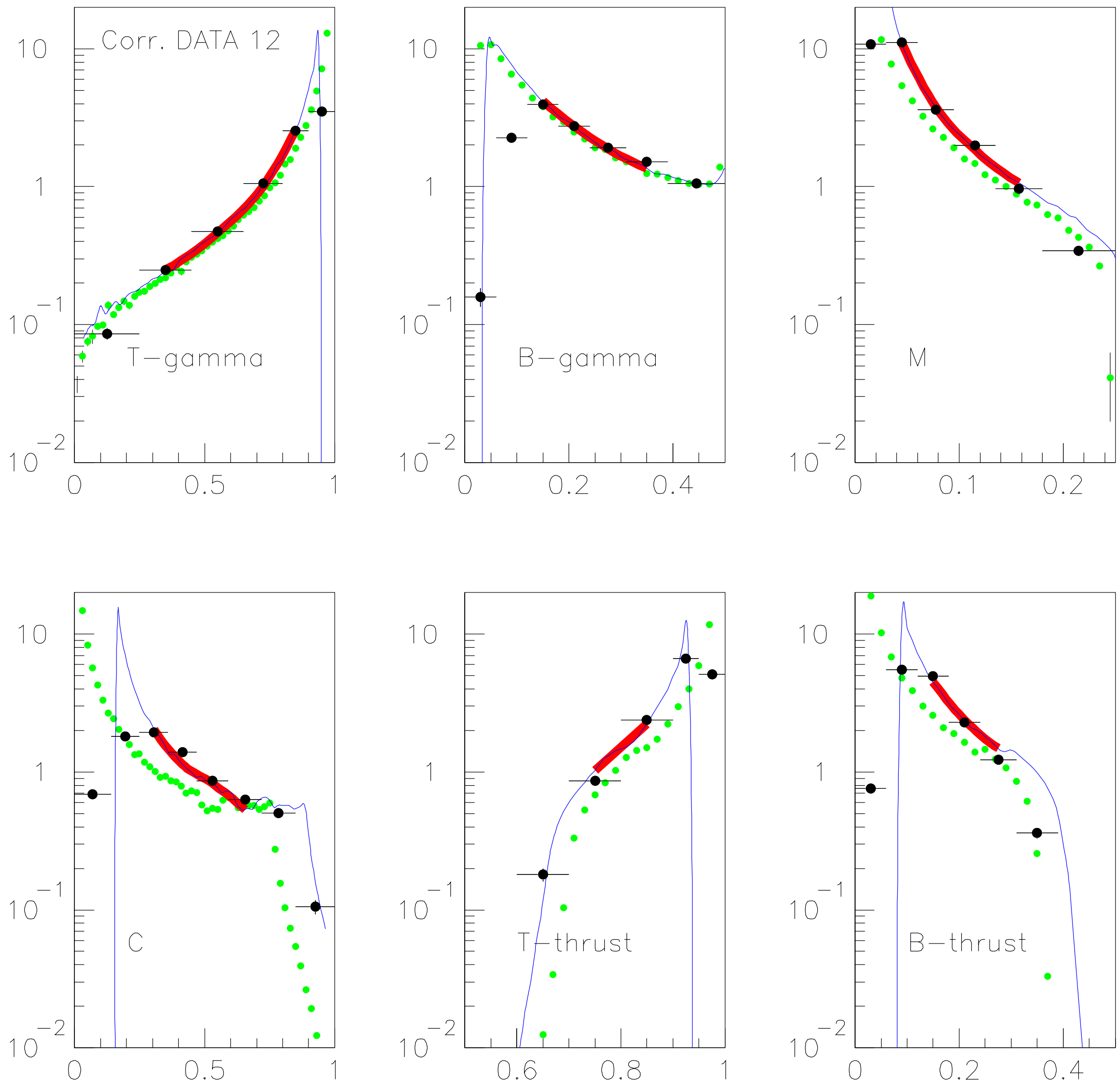
study the differential distributions



Agreement not based on errors shown

$5120 < Q^2 < 10240$ and $0.04 < x < 0.4$

Differential Distributions



Theory:

- **NLO can describe data by a simple SHIFT of NLO towards data**
- **SHIFT can be calculated for all event shapes**

Data well described for a limited region

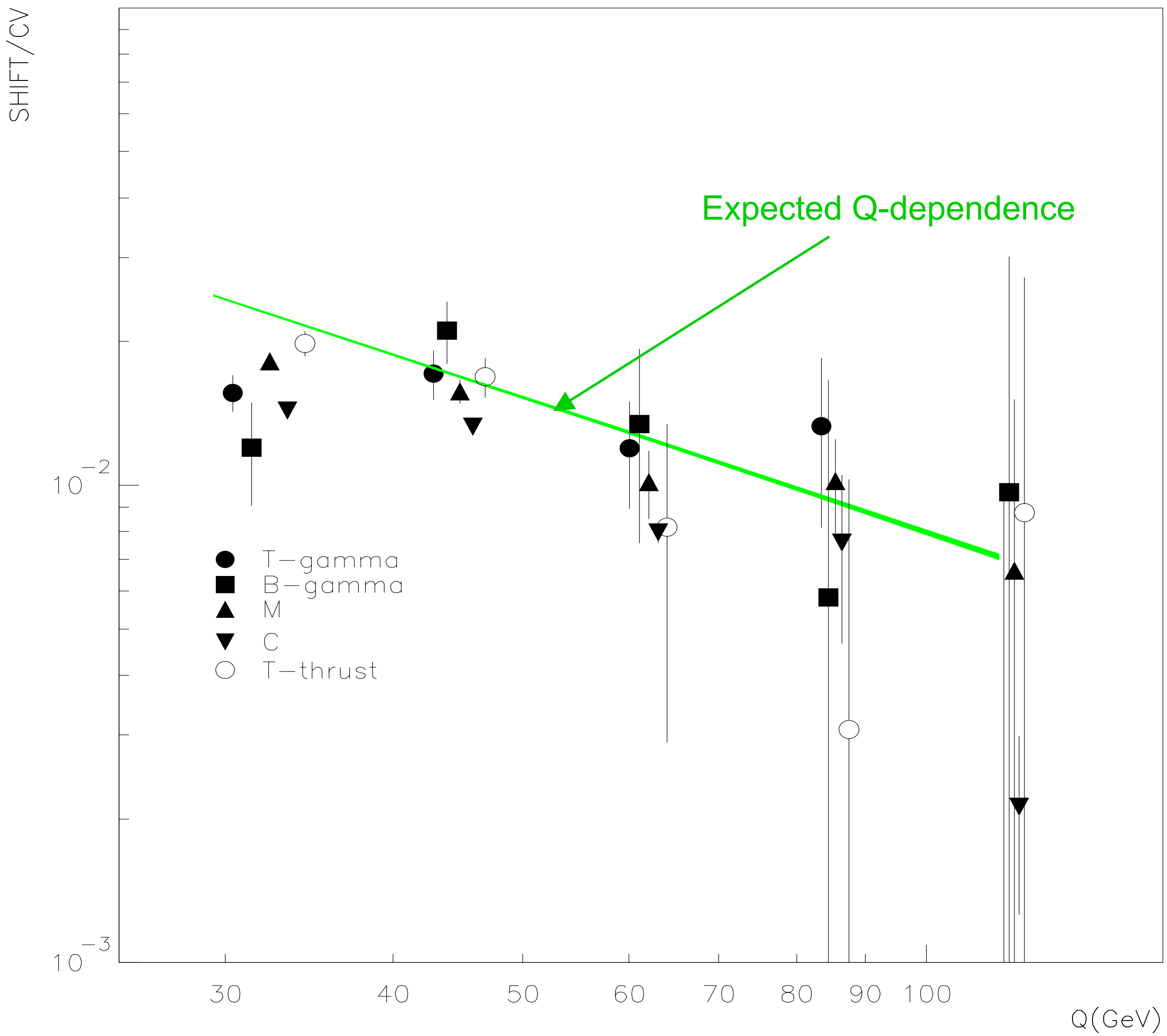
•	'98-'00 Data
•	DISASTER++
┌	Region of Fit
┌	Shifted NLO

Differential Distribution SHIFTS

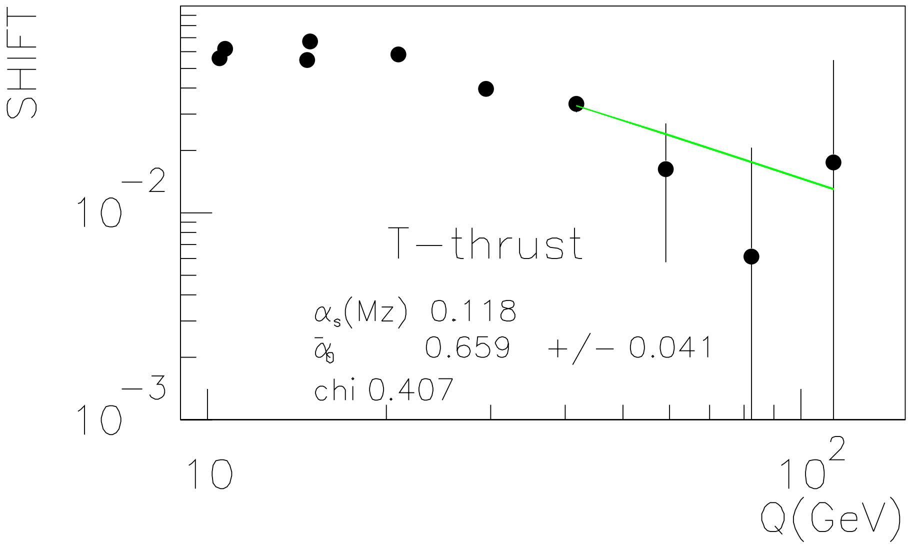
NLO shifts are proportional to a theoretically calculated constant value for each event shape

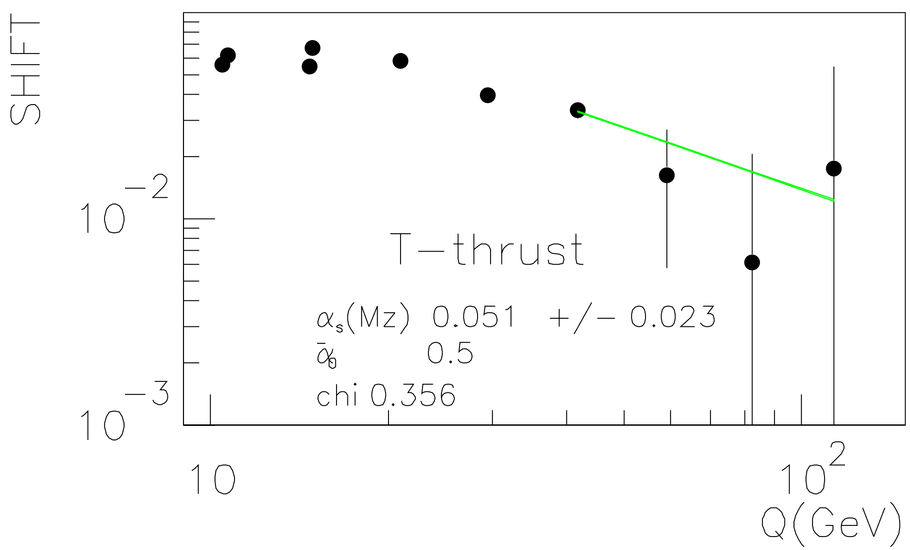
Reasonable agreement:

- normalized values of the shifts are grouped
- expected q-dependence is observed



Determine α_s, α_0 using shift values





Attempt to fit each event shape separately

Energy Flow and Dijets

Instead of inclusive events, we use dijets in the current region of the Breit frame

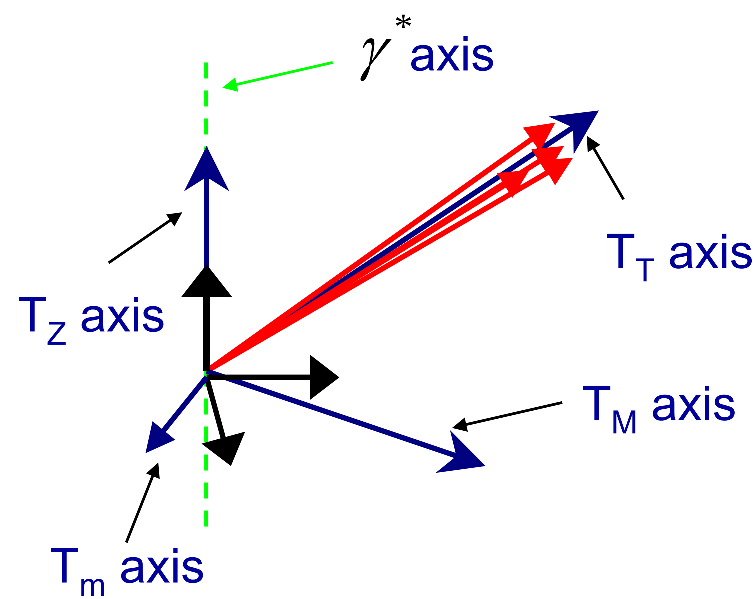
Dijets:

- pQCD part of <F> calculation well understood
- Event topology well understood

New Event Shape Variables: K_{out}, Azimuthal Correlation

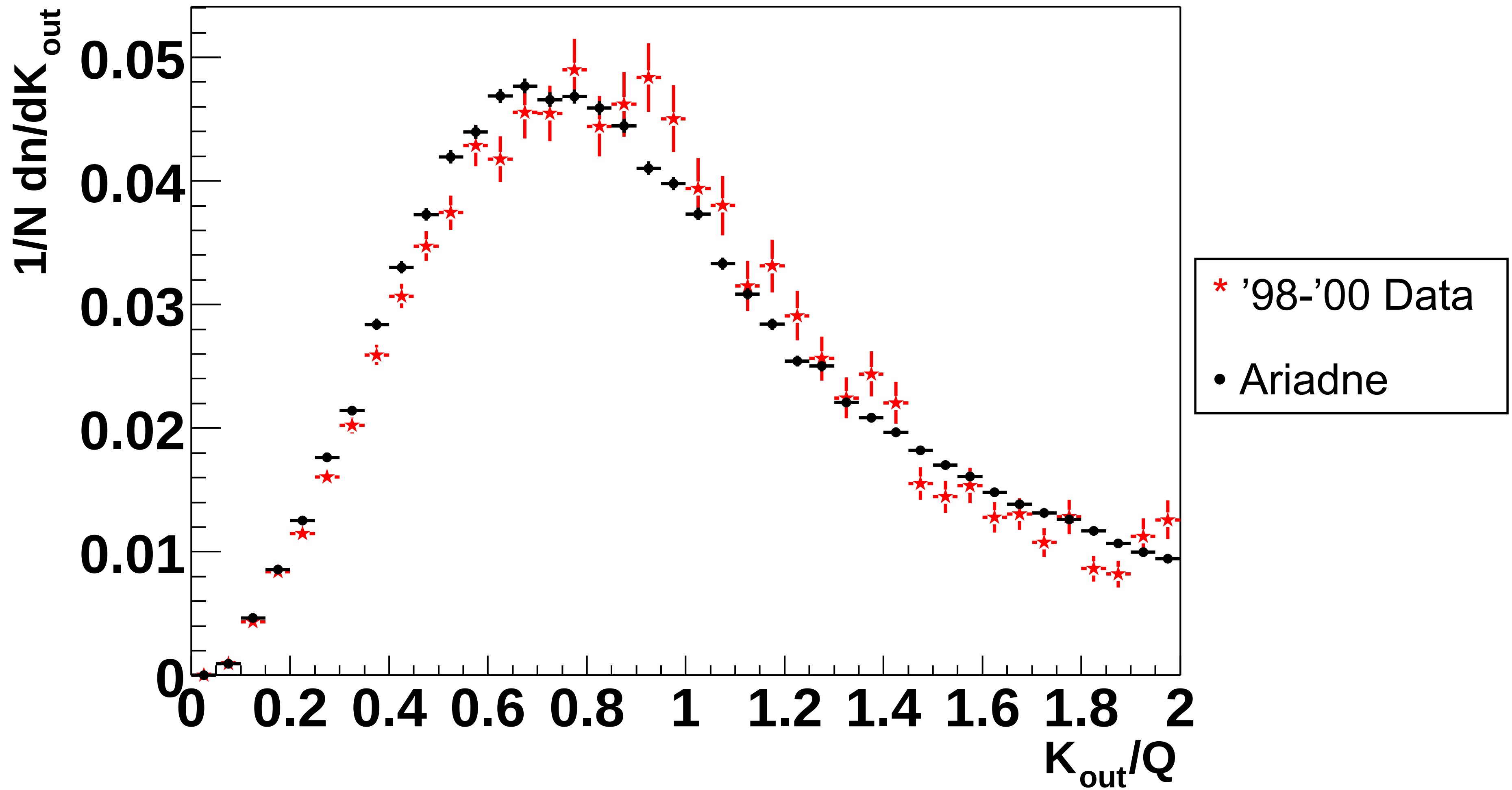
- Must define an event plane in the Breit frame
- Use Thrust to define the event plane
- Transverse Energy Flow

$$T_k = \max_{\hat{n}_k} \frac{\sum_i |\vec{p}_i \cdot \hat{n}_k|}{\sum_i |\vec{p}_i|}$$

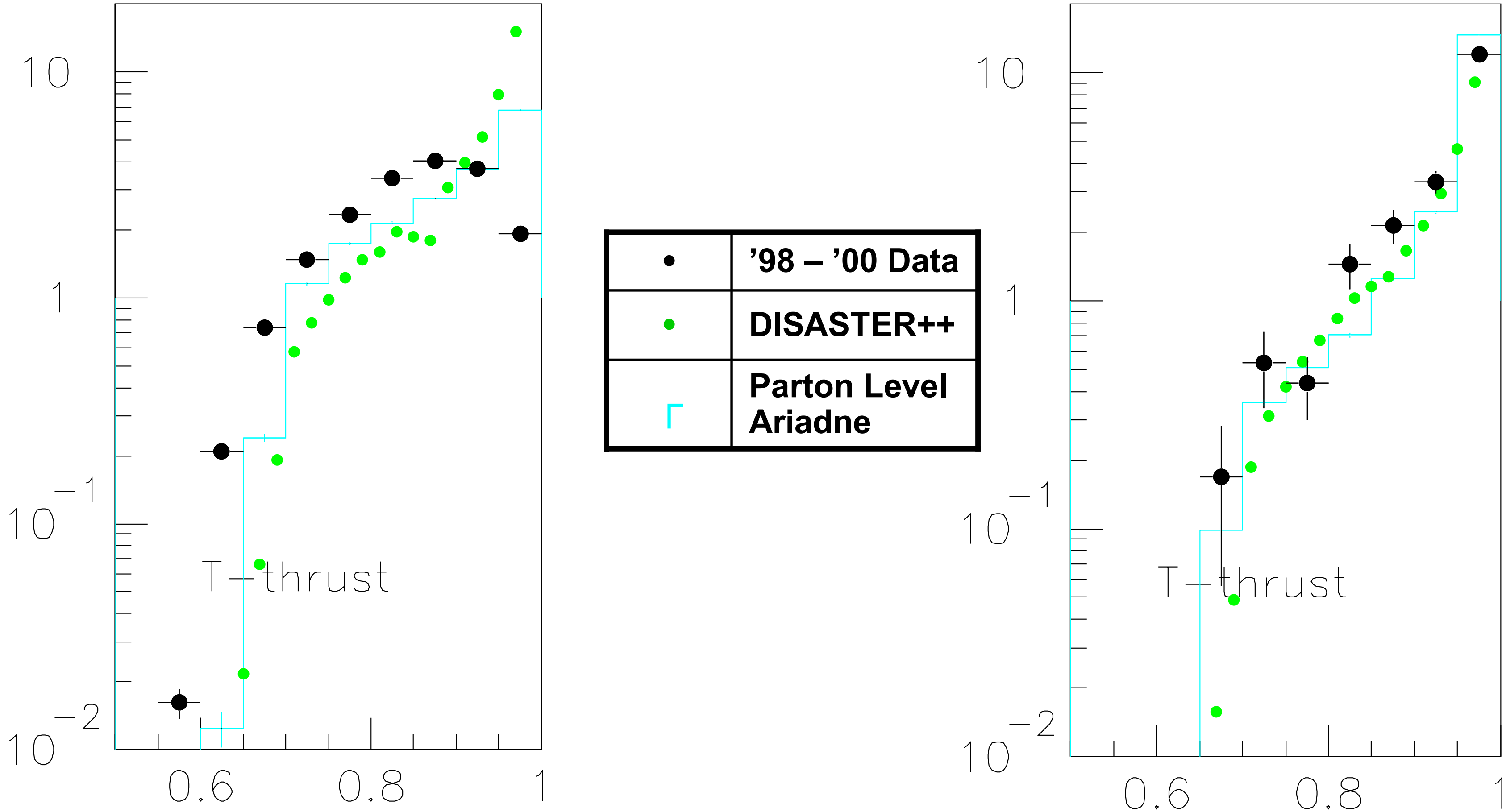


K_{out} Update

Progress for new variables.



New Methods to Study Hadronization



Leading Order MC hadronization correction to correct NLO.

Summary

Good agreement between ‘96-’97 published and current ‘98-’00 analyses

Good agreement between Glasgow and Wisconsin analyses

Differential Distributions are still not very promising

New event shapes are well described by the LO MC

Plans:

- More work on differential distributions
- Power corrections for the new event shapes
- New way of hadronization using LO MC

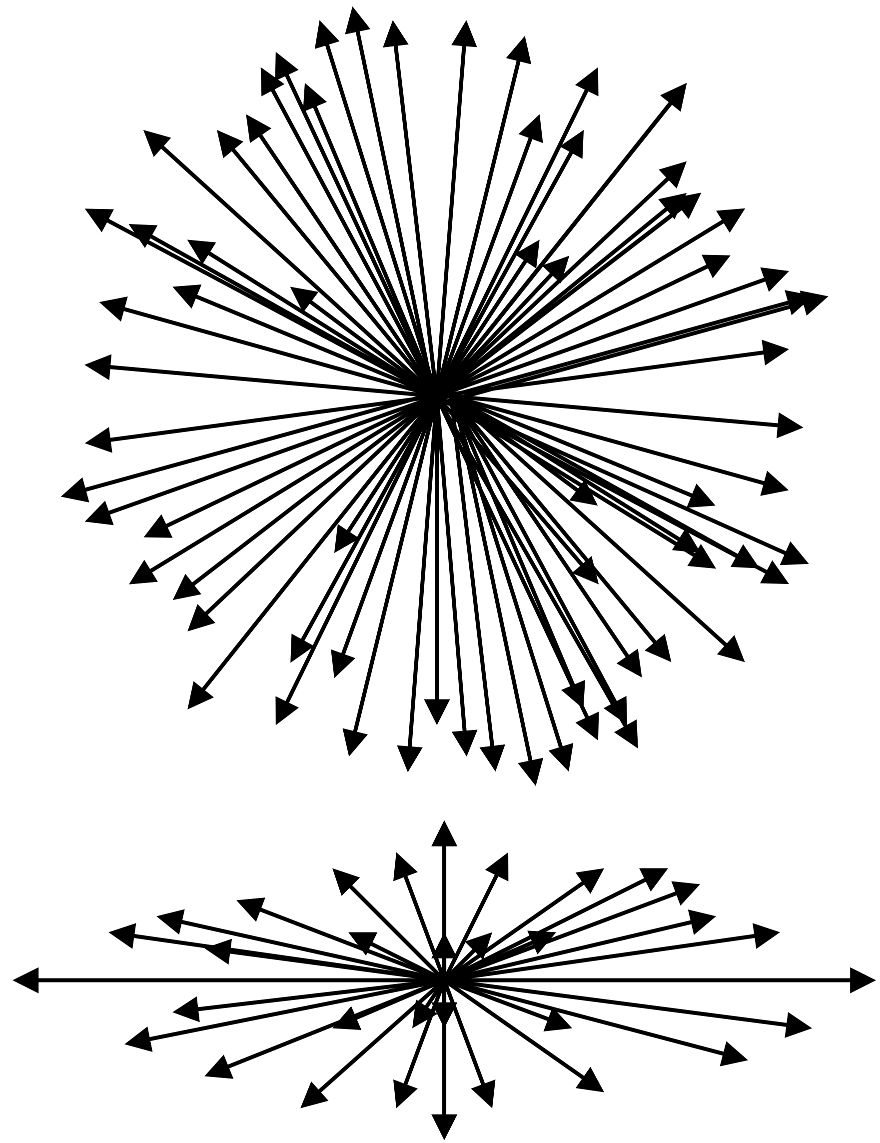
Appendix

The following slides form an appendix to explain and define various event shape variables

Sphericity

Describes isotropy of energy flow

- **Measure of the summed p^2_T wrt. Sphericity axis**



$$S = \frac{3}{2}(\lambda_2 + \lambda_3)$$

$$S^{\alpha\beta} = \frac{\sum_i p_i^\alpha p_i^\beta}{\sum_i |\vec{p}_i|^2}$$

$$0 \leq S \leq 1$$

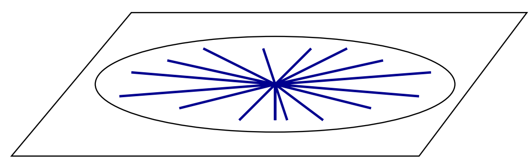
Aplanarity

Describes energy flow out of Sphericity evt. plane

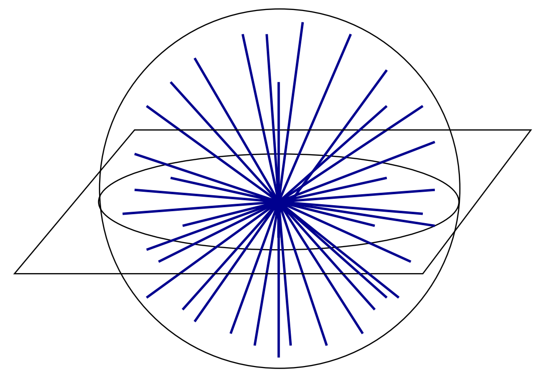
- **Measure of p_T out of plane**

$$A = \frac{3}{2}\lambda_3 \qquad 0 \le A \le \frac{1}{2}$$

S=A=0



S=3/4 A=0



S=1 A=1/2

Axis Independent Variables

Jet Mass

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

C Parameter

$$C = \frac{3\sum_{ij} \vec{p}_i \vec{p}_j \sin^2(\theta_{ij})}{2\sum_{ij} \vec{p}_i \vec{p}_j}$$

Thrust in DIS

Linear collimation of hadronic system along a specified ("thrust") axis

T interpretation depends on choice of axis:

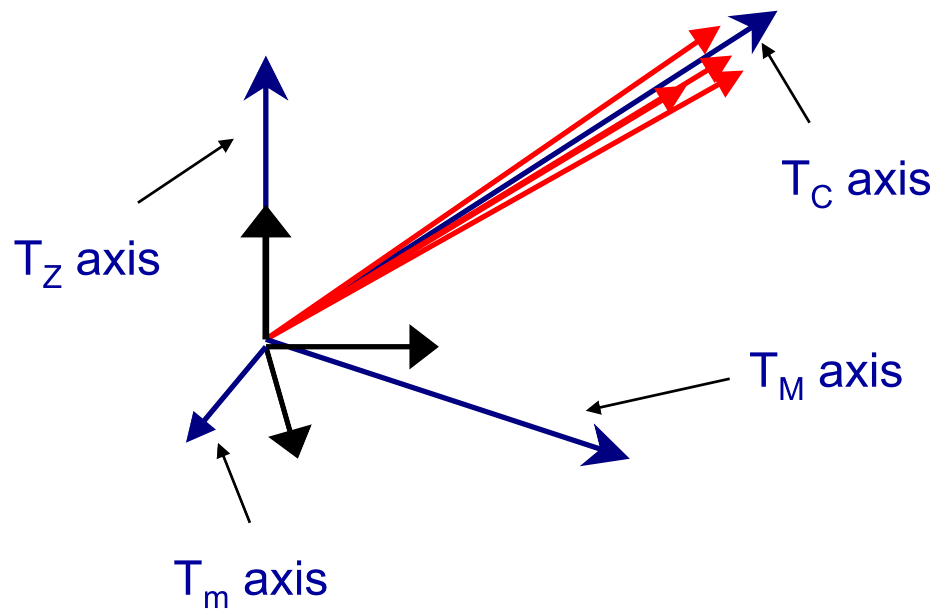
- **Four Thrusts in DIS: T_Z, T_M, T_m, T_C**

$$T_k = \max_{\hat{n}_k} \frac{\sum_i |\vec{p}_i \cdot \hat{n}_k|}{\sum_i |\vec{p}_i|}$$

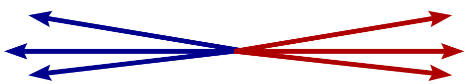
$$\hat{n}_M \cdot \hat{z} = 0 \quad \hat{n}_m \cdot \hat{z} = 0$$

$$k = C, M, m$$

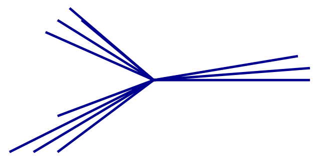
$$\tfrac{1}{2} \le T \le 1$$



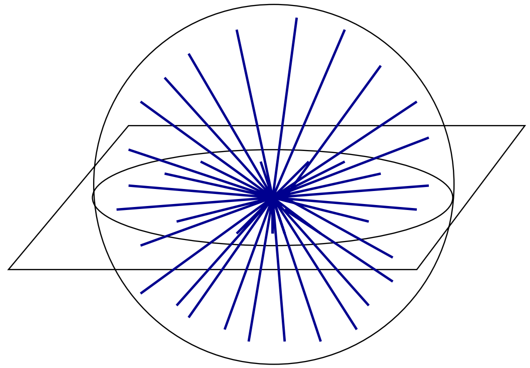
Thrust and Sphericity



T=1 S=0



T=3/4 S=1/2

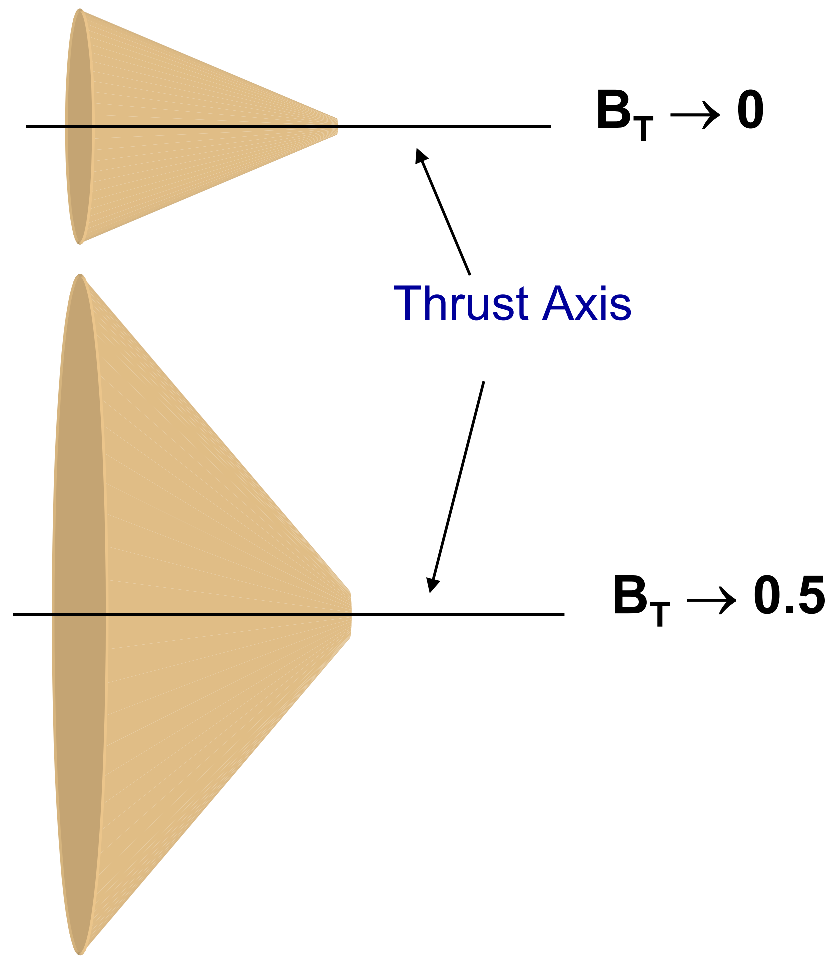


S=1 T=1/2

Broadening

Broadening of particles in transverse momentum wrt. thrust axis

$\Rightarrow$ **B_T, B_W**



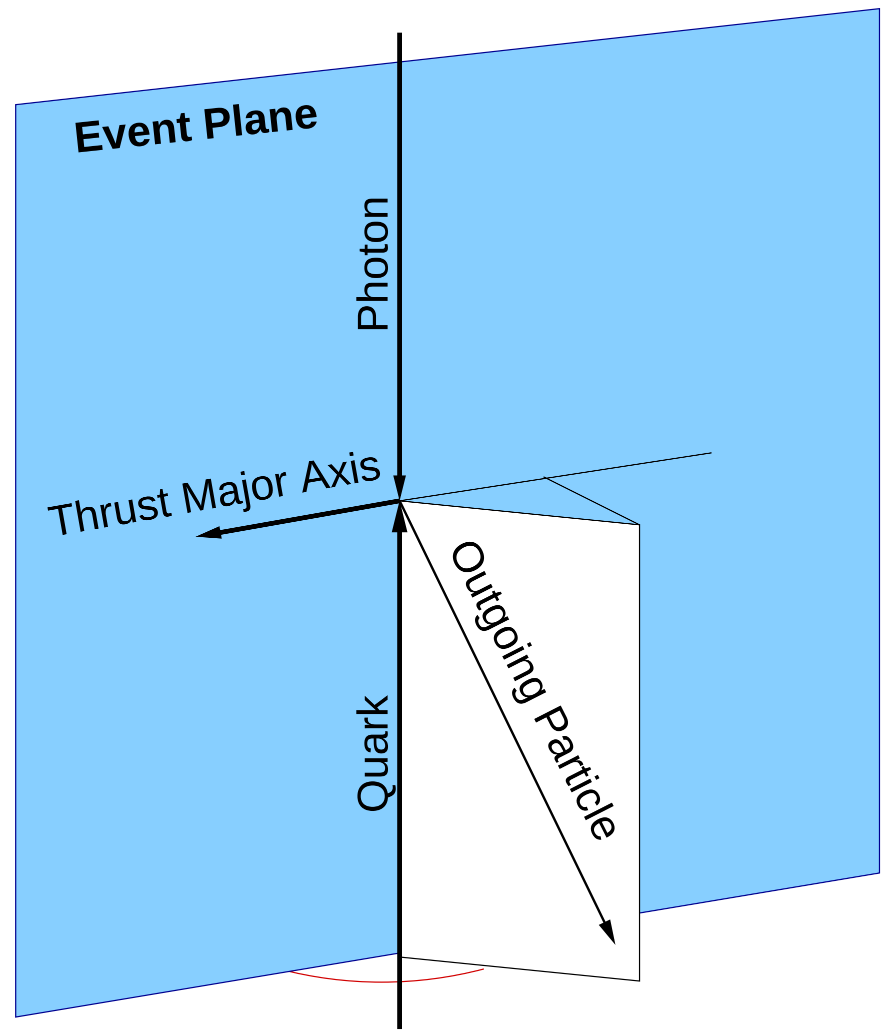
$$B_k = \frac{\sum_i |\vec{p}_i \times \vec{n}_T|}{\sum_i |\vec{p}_i|}$$

$$B_T = B_1 + B_2$$

$$B_W = \max\{B_1, B_2\}$$

Out-of-plane Momentum

Energy flow out of event plane defined by proton direction and thrust major axis



$$K_{out} = \sum_{h}^{'} \left| p_h^{out} \right|$$

Azimuthal Correlation

Momentum weighted function of the azimuthal angle around the photon-proton axis in the Breit frame between pairs of hadrons.

$$H(\chi)=\sum_{h,h'}\frac{p_{th}p_{th'}}{Q^2}\delta(\chi-\chi_{hh'})$$

$$\phi_{hh'}=\phi_h-\phi_{h'} \qquad -\pi<\phi_{hh'}<\pi$$

$$\chi_{hh'}=\pi-|\phi_{hh'}| \qquad 0\le\chi\le\pi$$