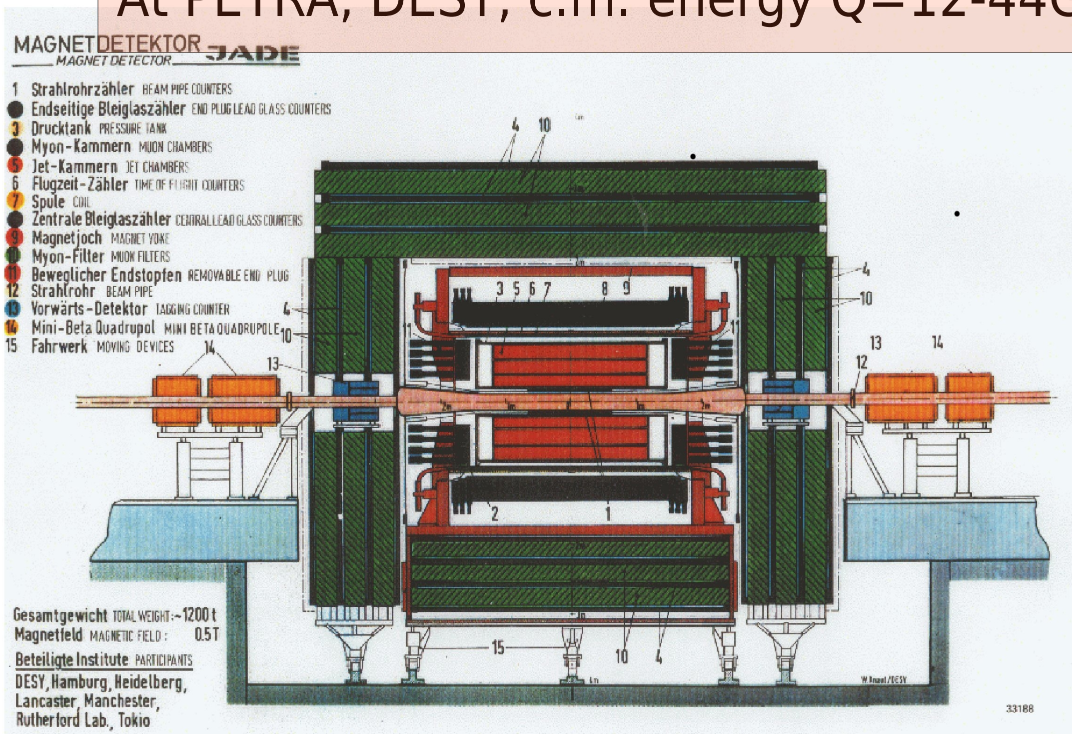
Determinations of α_s and tests of analytic hadronisation models using e^+e^- annihilation data.

S. Bethke, O. Biebel, S. Kluth, C. Pahl*, J. Schieck and the JADE Collaboration

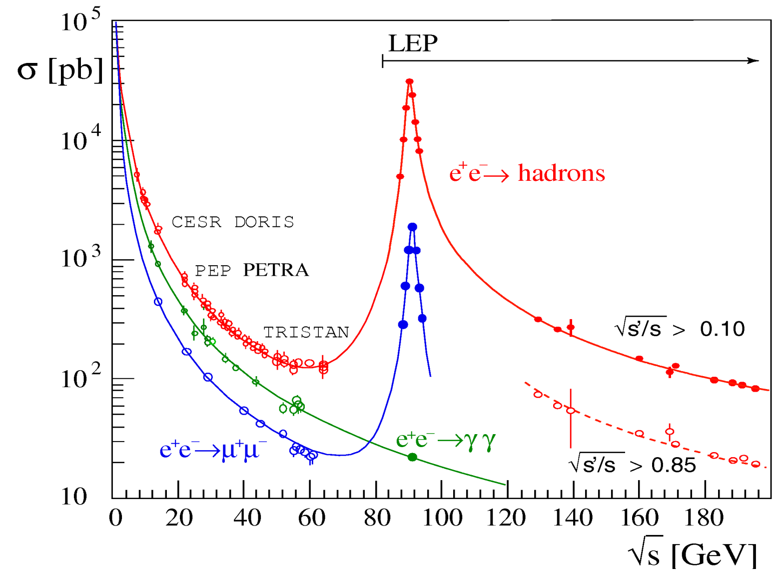
- JADE experiment
- Event shape distributions and moments
- Analysis of moments from JADE and OPAL using analytic hadronisation models **(arXiv:0810.1389)**
- Measurement of α_s from JADE distributions using new NNLO calculations **(arXiv:0904.0786)**
- Conclusion and outlook

JADE Experiment, 1978-1986

At PETRA, DESY, c.m. energy Q=12-44GeV



hadronic cross section



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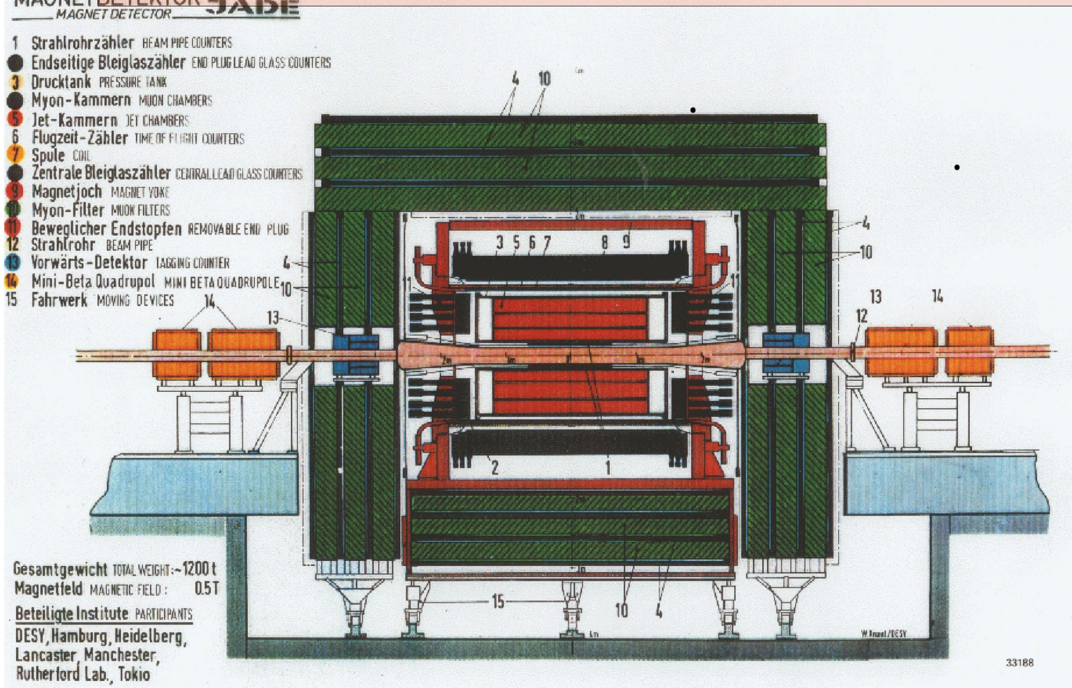

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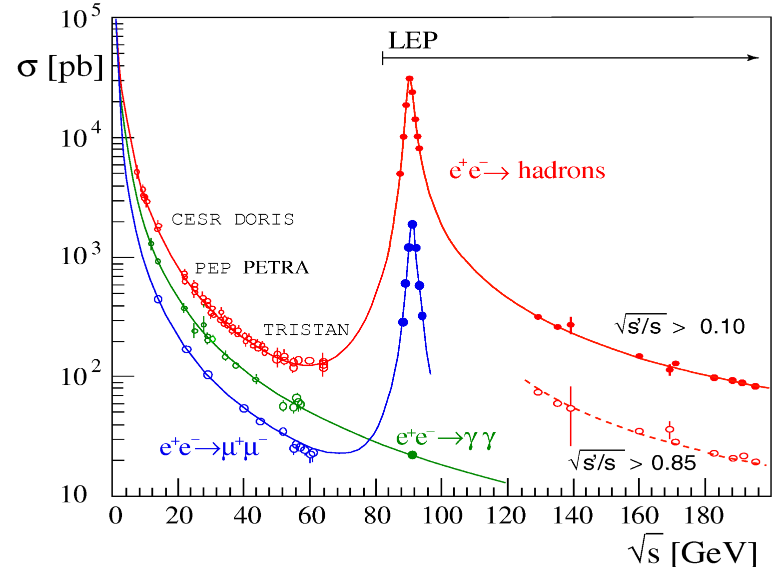

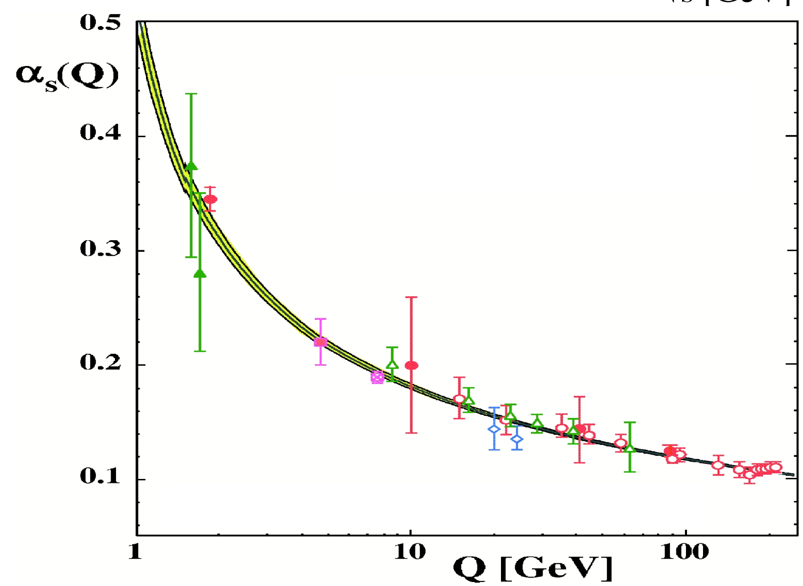

- QCD effects stronger at low Q

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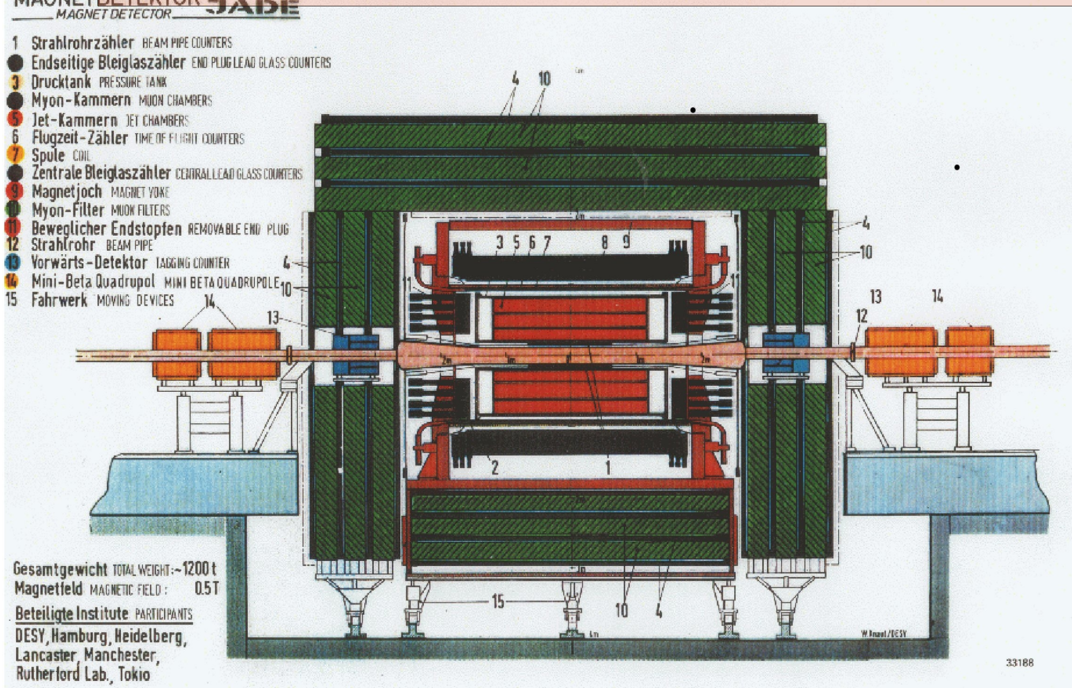

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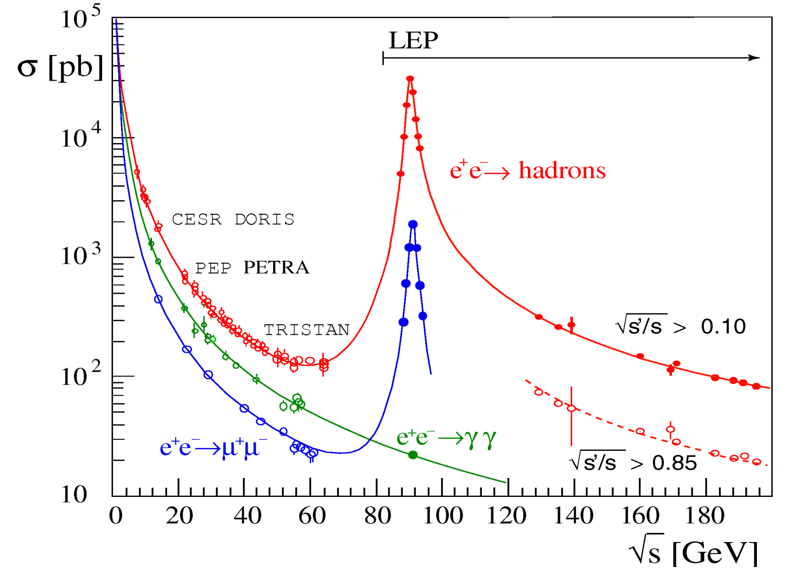

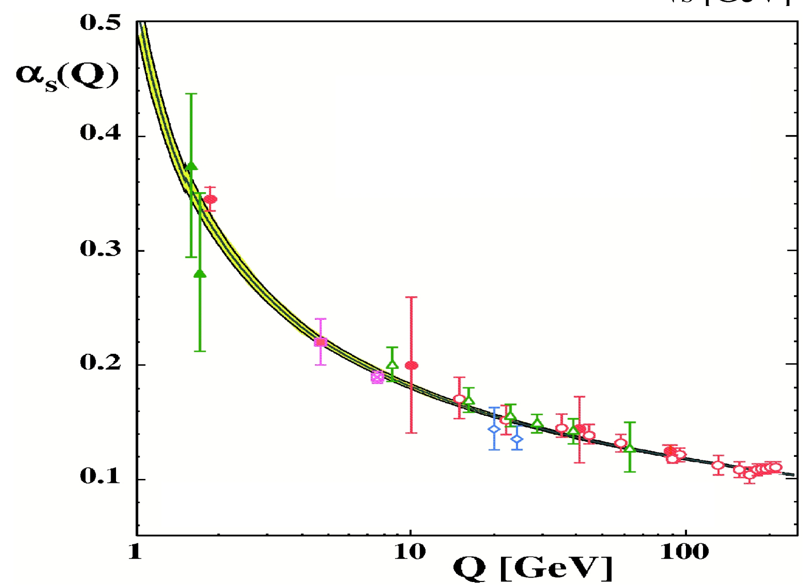

- QCD effects stronger at low Q
- Old data saved from tapes, printouts.
- Analysis and detector simulation software reactivated
- New Monte Carlos, new calculations

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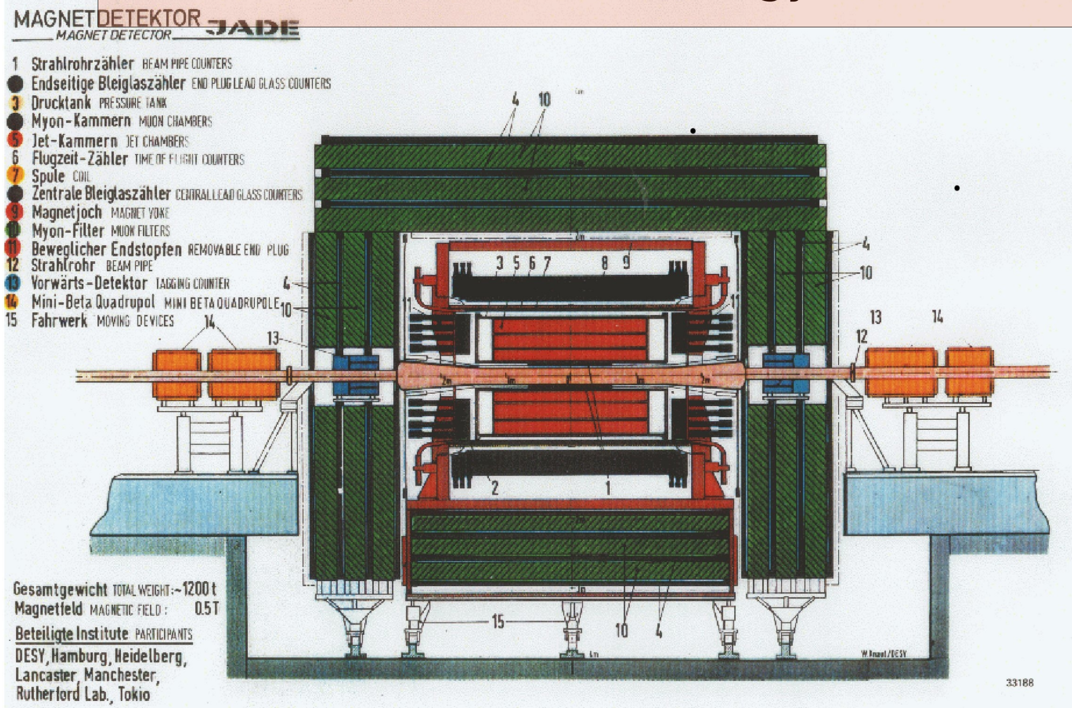

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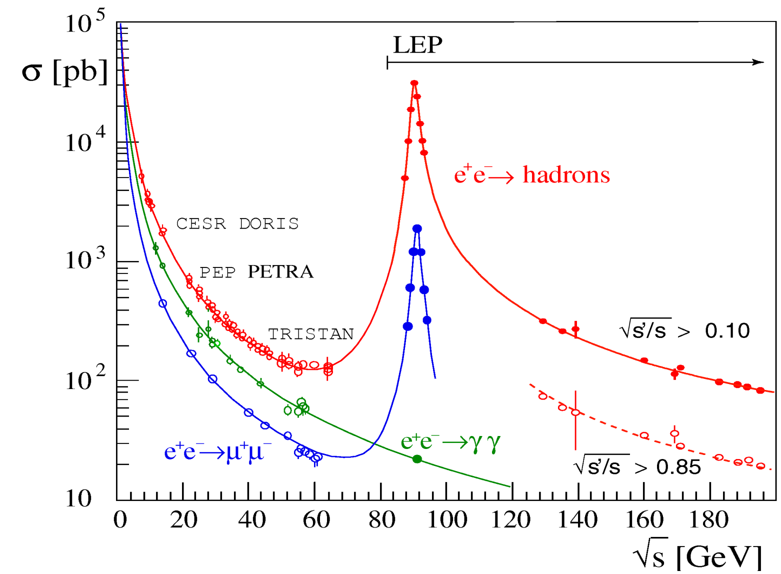

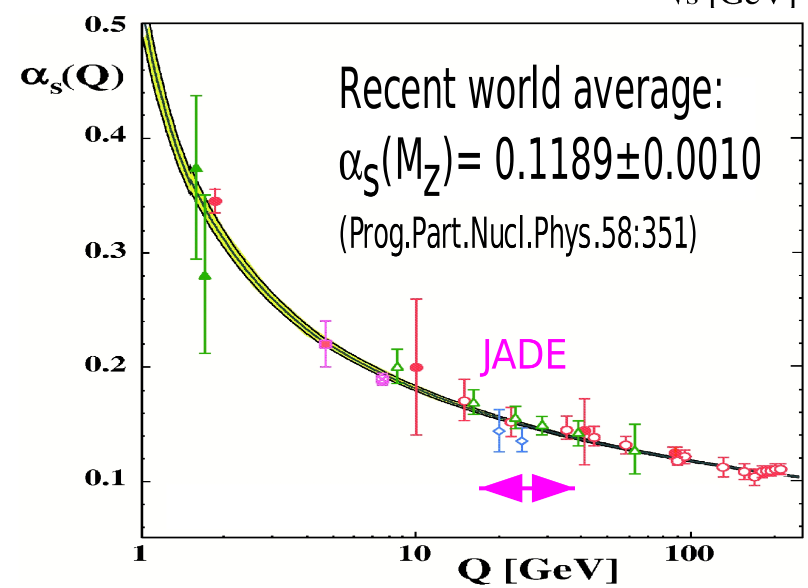

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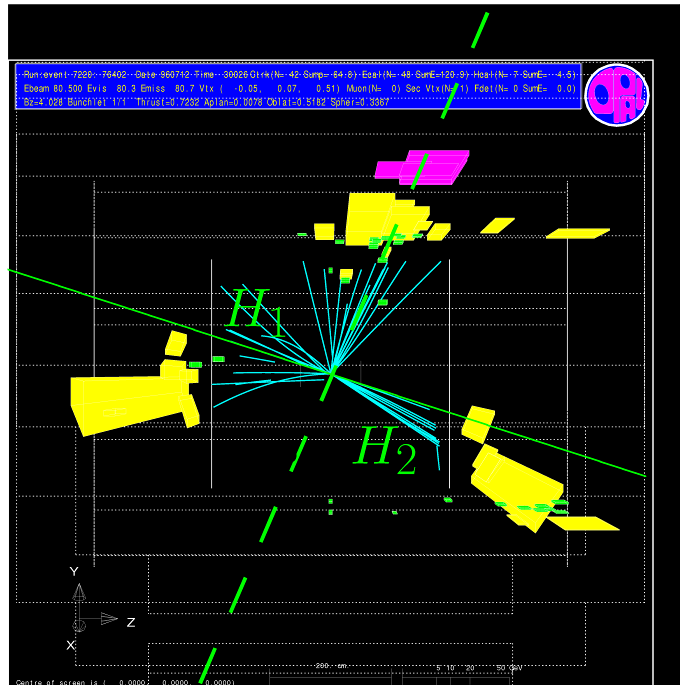
Event shape variables y

- Thrust 1-T
- C-parameter
- Total Jet Boadening B_T

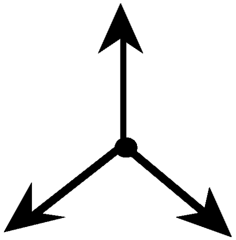
(Two-hemisphere variables)



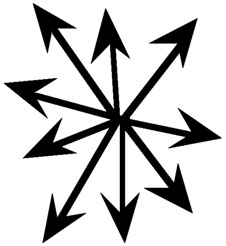
- Wide Jet Broadening B_W
- Durham two-jet flip parameter y_{23}^D
- Heavy Jet Mass M_H

(One-hemisphere variables)

qq: 2 Jets, y≈0



qqg: 3 Jets, e.g. 1-T ≈ ⅓

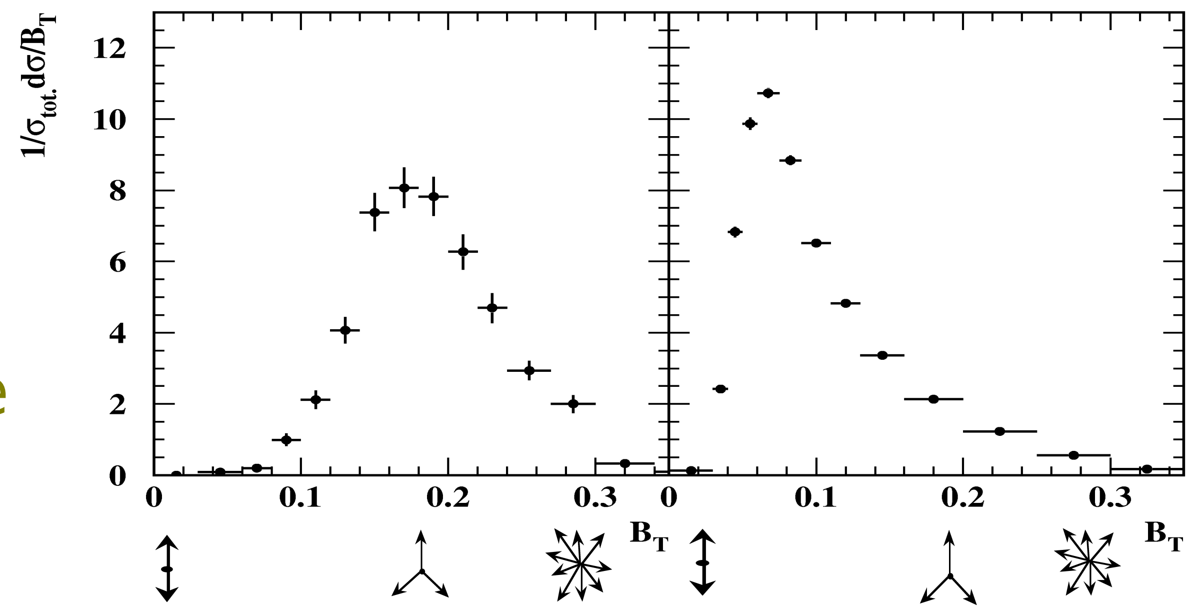


Many gluons, e.g. 1-T ≈ ½

Distributions and moments

- Distributions

B_T at 14 GeV: α_s large

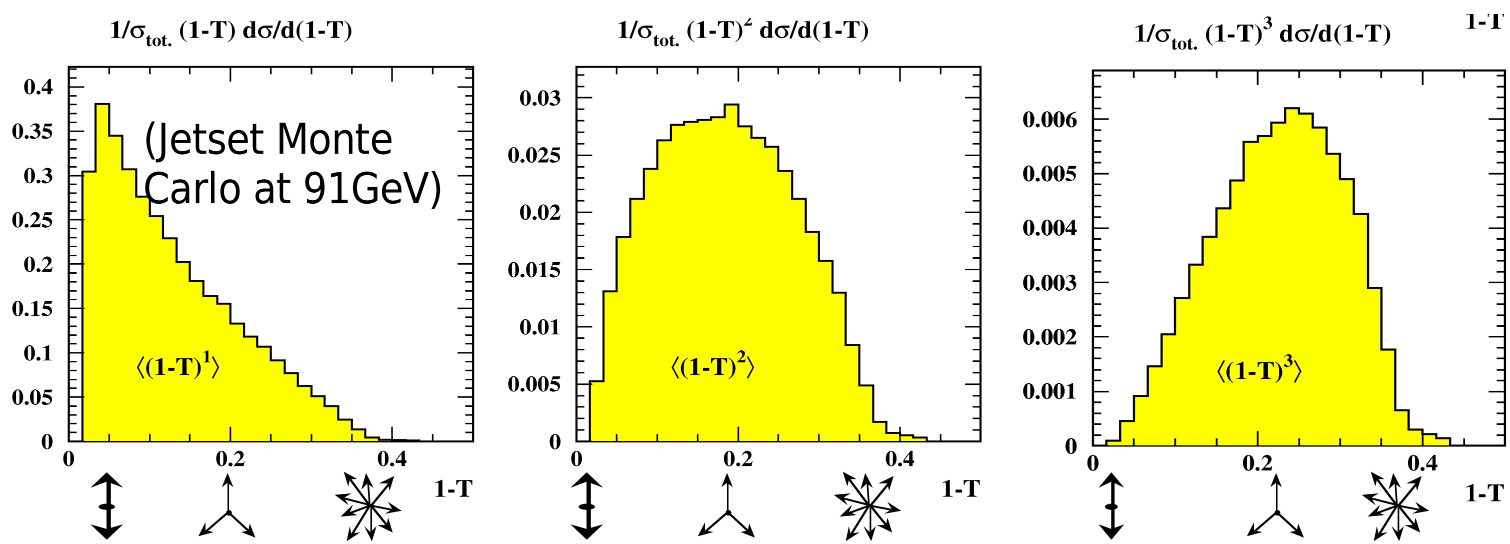


B_T at 91 GeV: α_s small

- Moments

$$\langle y^n \rangle = \int y^n \frac{1}{\sigma} \frac{d\sigma}{dy} dy$$

Higher order moments probe the multi-jet region:

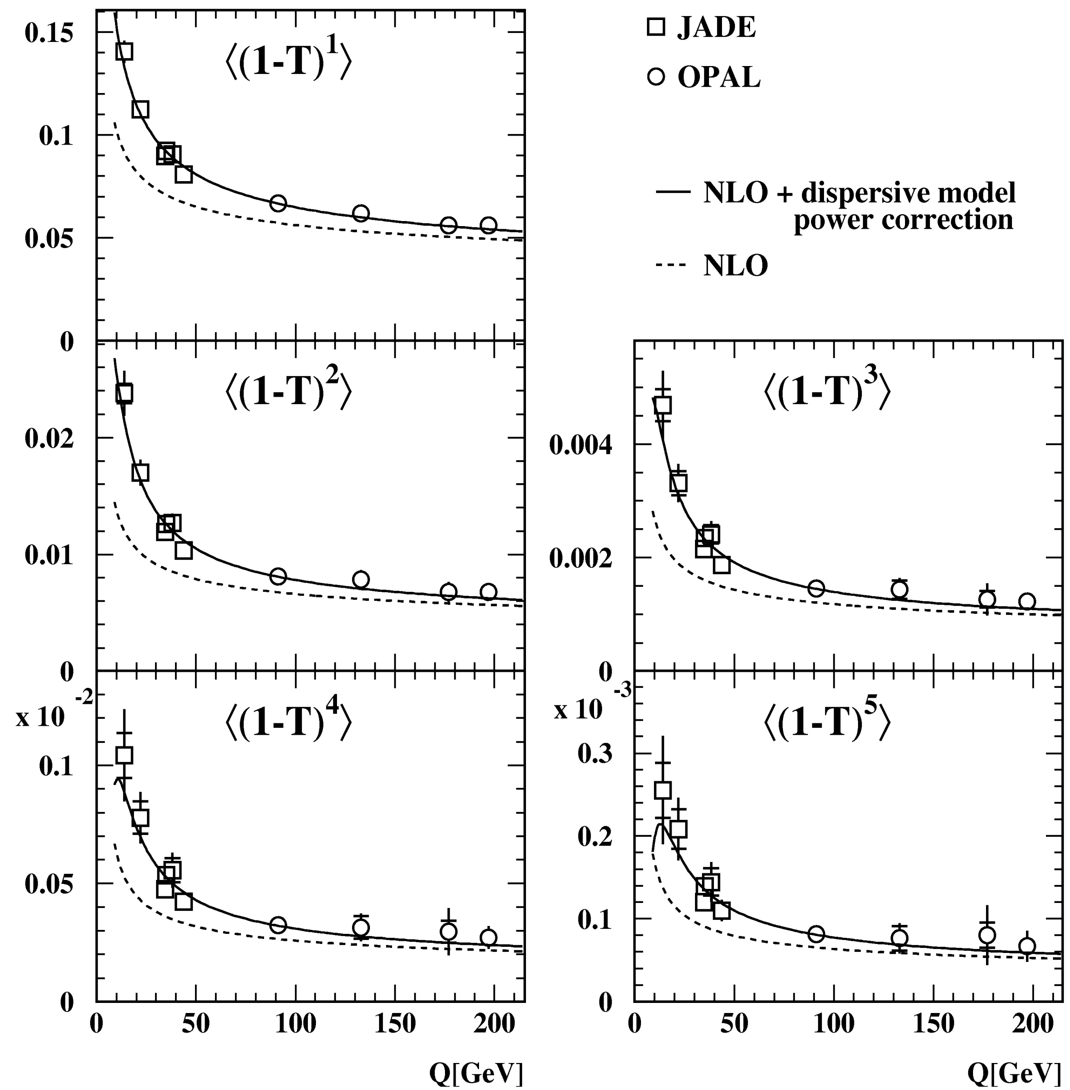


Testing QCD: Fits to the moments

- $\langle y^m \rangle$, m=1…5 measured by JADE and OPAL
- Hadronisation correction by **analytical "non perturbative" power correction models**
- Perturbative predictions: **N**ext to **L**eading **O**rder,

$$\langle y^n \rangle = A_n \alpha_s(Q^2) + B_n \alpha_s^2(Q^2)$$

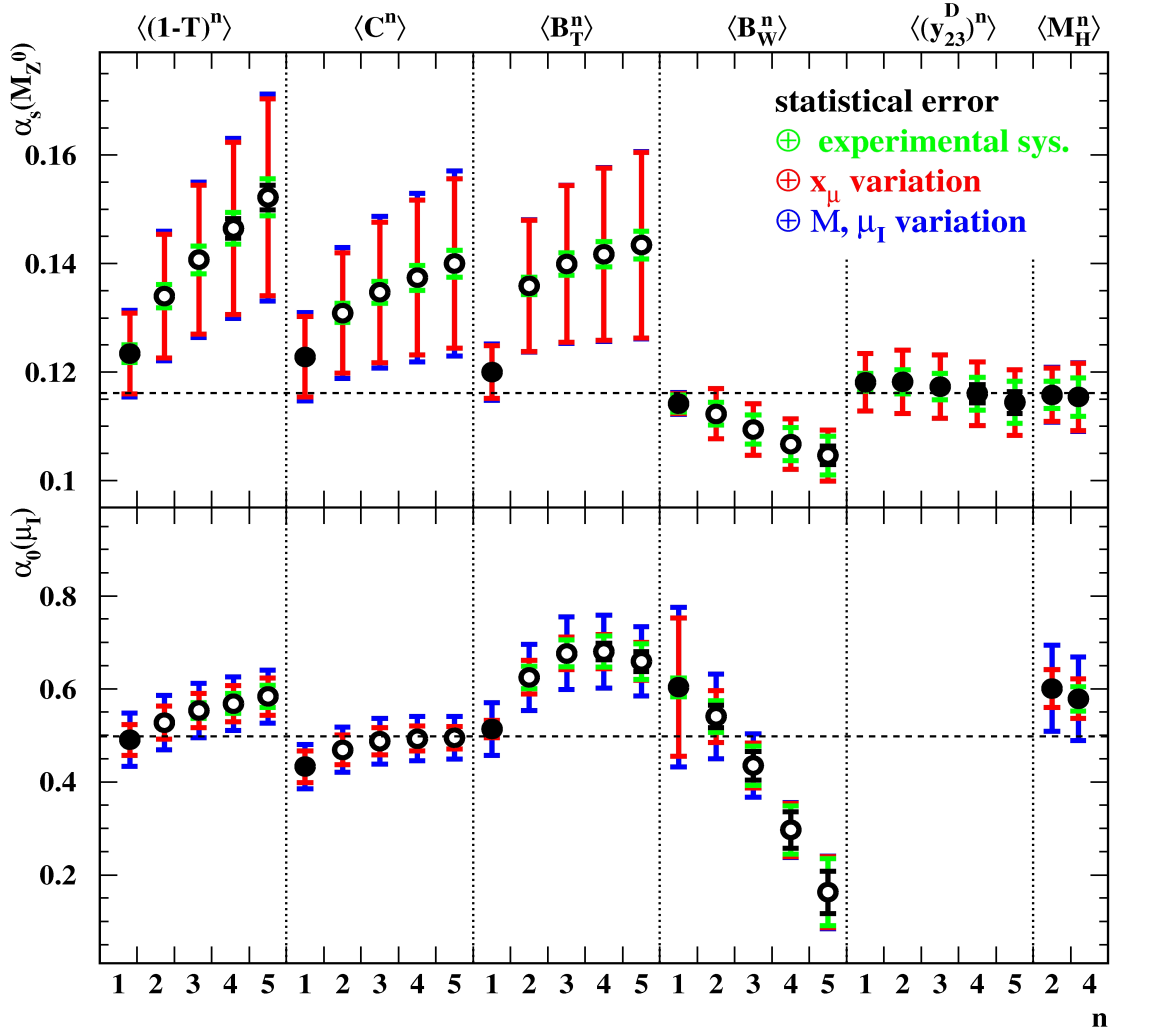
Fits to moments of Thrust on hadron level



Testing QCD: Fits to the moments

- Dispersive model (Dokshitzer et al.): $$\frac{d\sigma_{had.}}{dy} = \frac{d\sigma_{pt.}}{dy}\left(y - a_y * P(\alpha_0)\right)$$

Dispersive model: Measurements of $\alpha_S(M_Z)$ and α_0



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  Deficiencies of the NLO predictions lead to non universalities of the fit parameters:
  - Significant rise of $\alpha_S(M_{Z^\circ})$ with moment order n for two-hemisphere moments
  - higher α_0 for one-hemisphere moments

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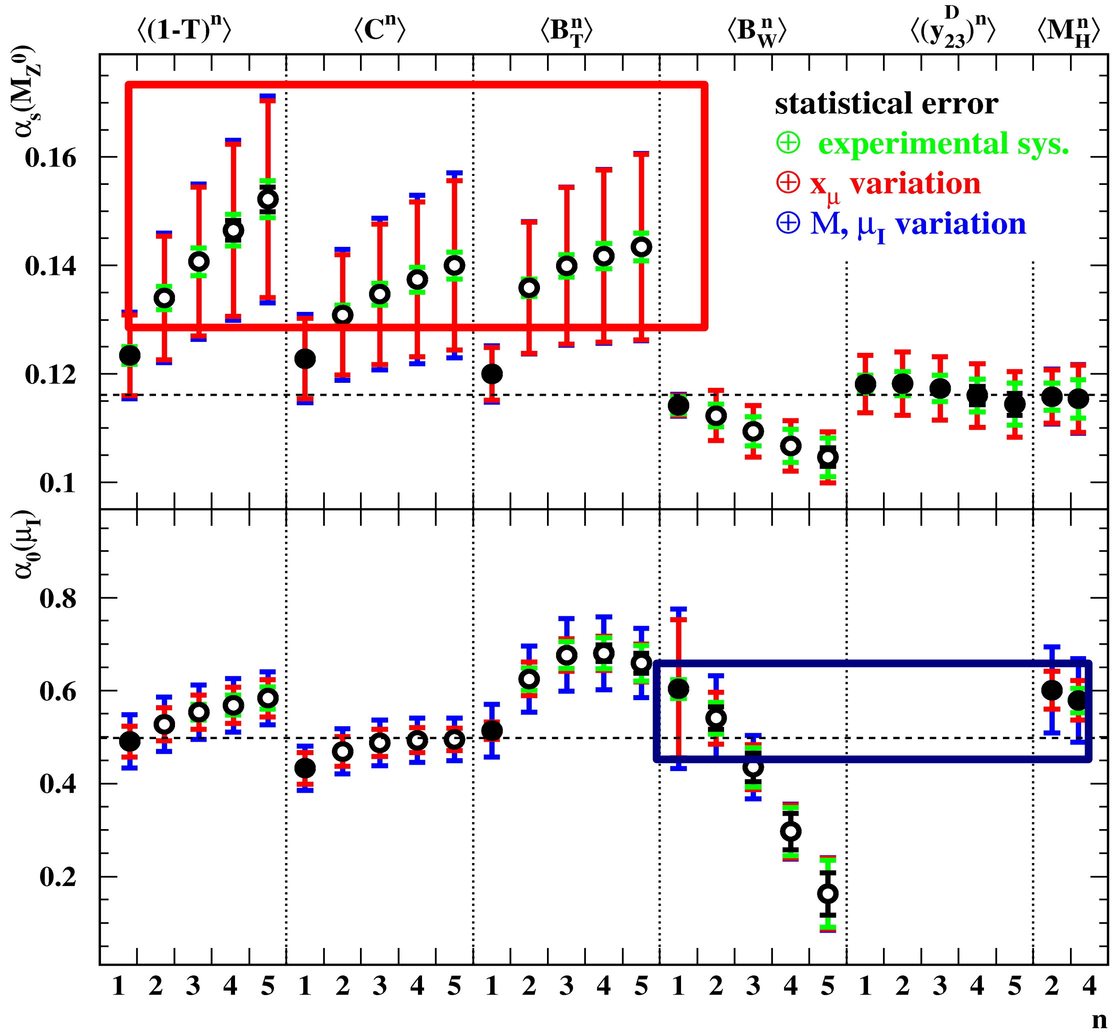

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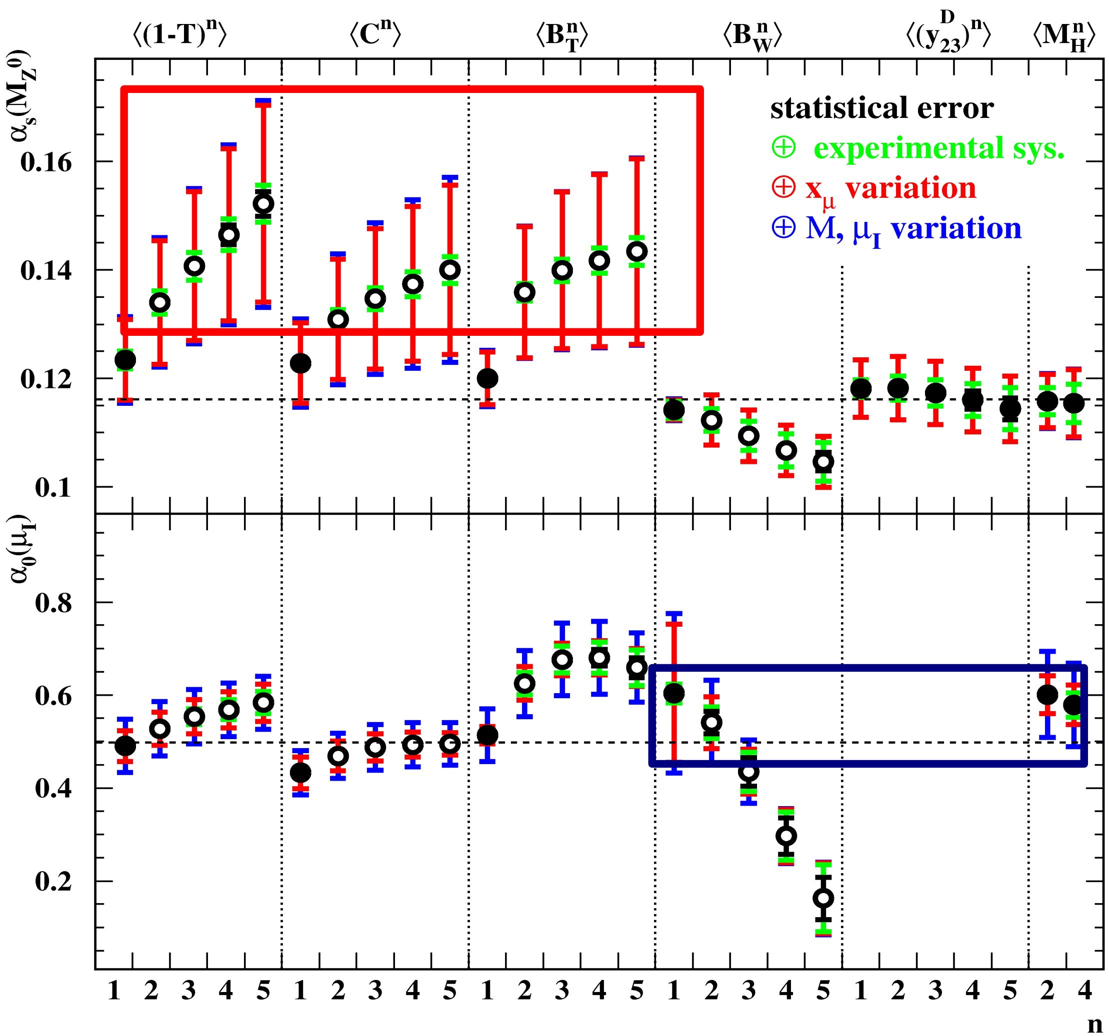
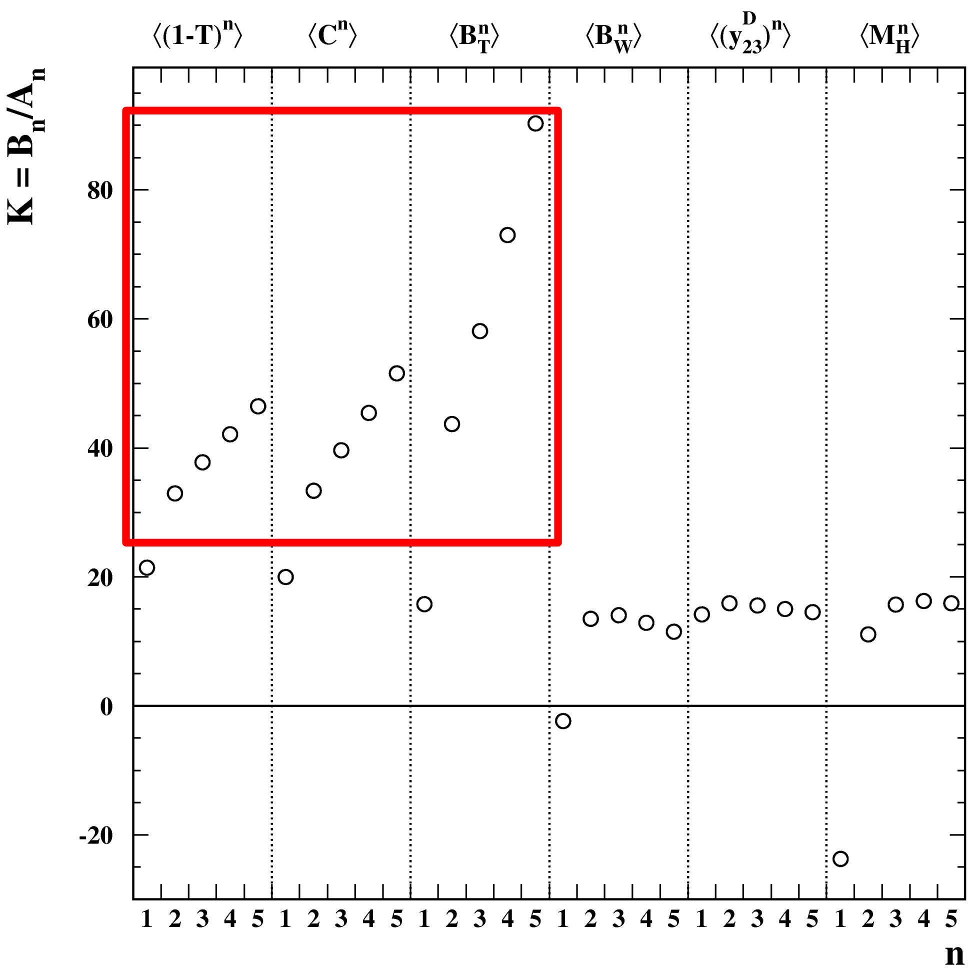
- Shape Function (Korchemsky)
- Single dressed gluon approximation (Gardi et al.): **$\alpha_S(M_Z)$=0.1172±0.0036**

Dispersive model: Measurements of $\alpha_S(M_Z)$ and α_0



Testing QCD: Fits to the moments

Predictions: $K = B_n/A_n$



NLO calculations: Two-hemisphere moments receive large corrections in α_s^2.

Fit results: Trend seems to continue...

Testing QCD: Fits to the moments

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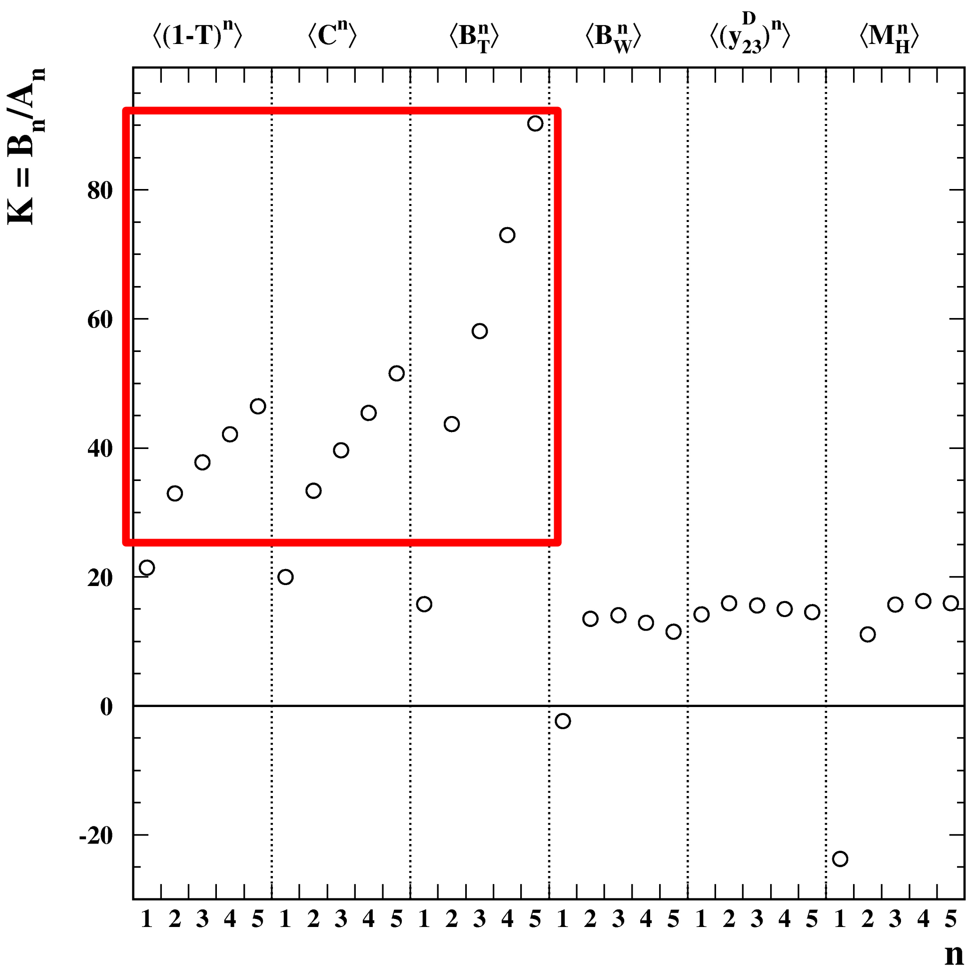

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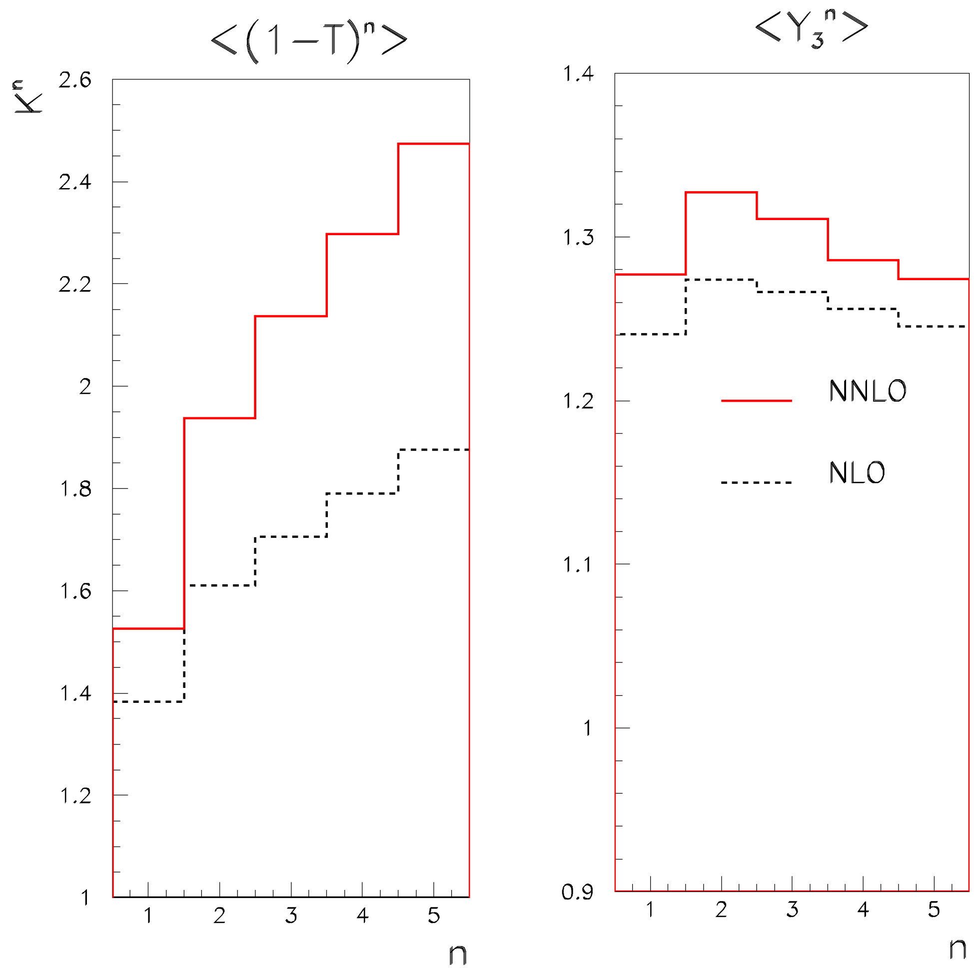
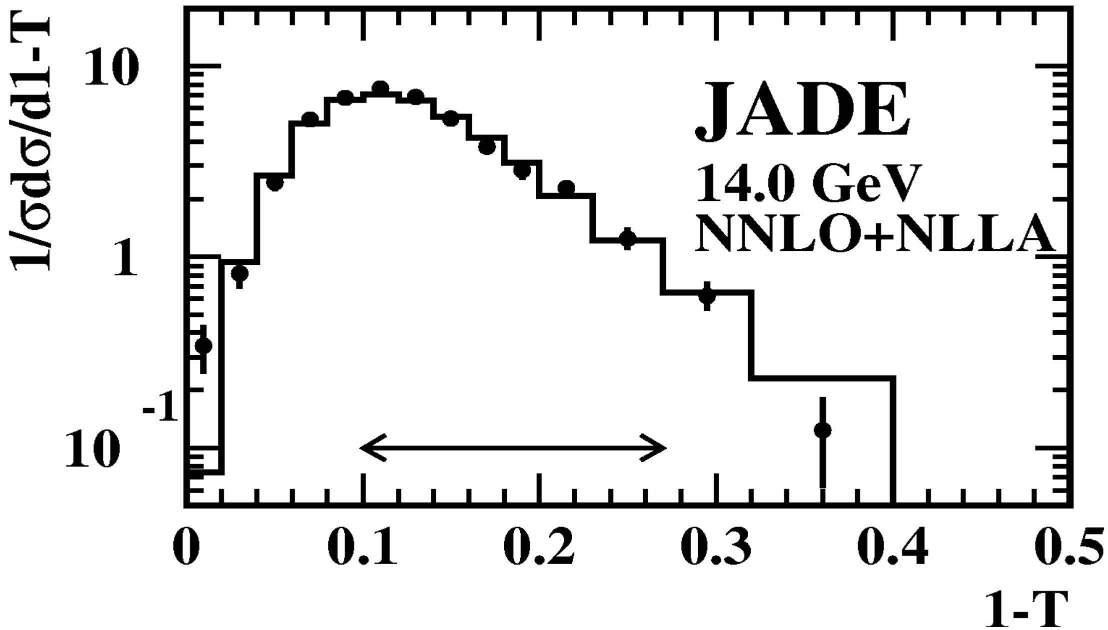
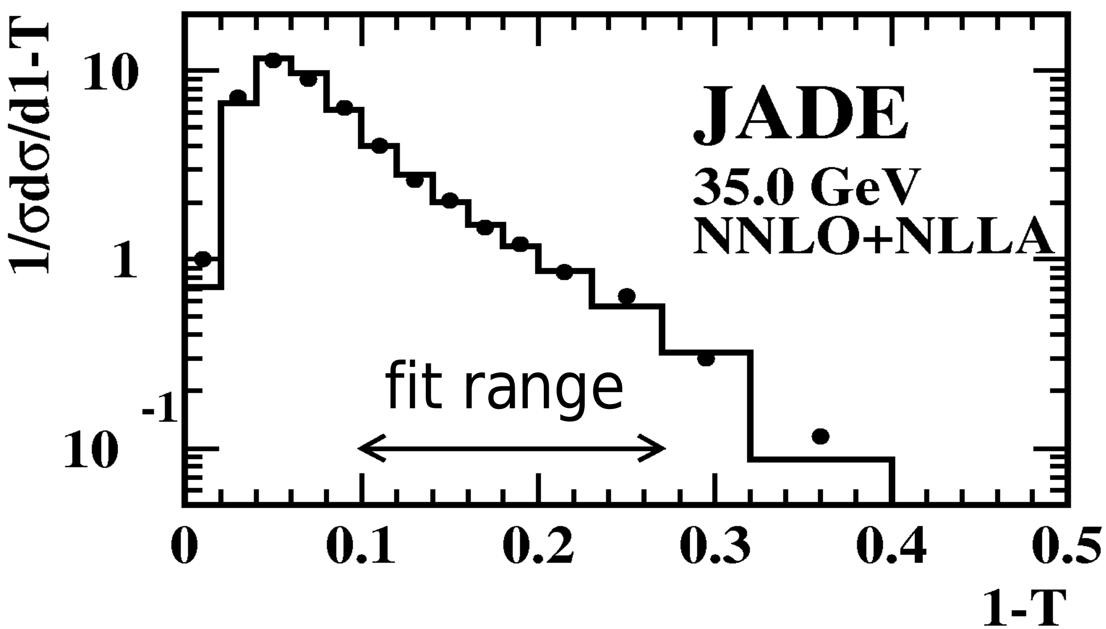
NNLO/LO



New: Theoretical explanation (JHEP 0905:106, 2009)

Measuring α_s: New NNLO calculations

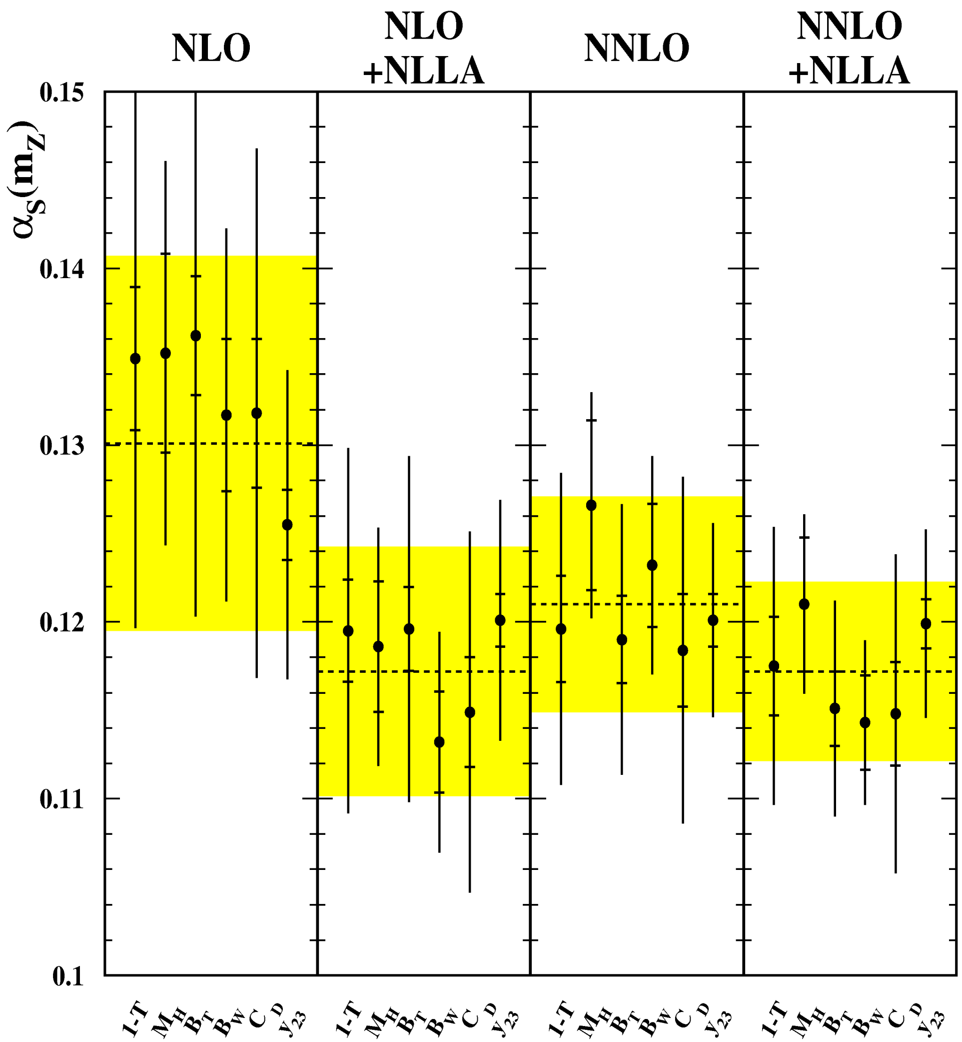




- Predictions: **N**ext to **N**ext to **L**eading **O**rder O(α_s^3) (finished 2008 after 25 years) + **N**ext to **L**eading **L**ogarithmic **A**pproximation
- Hadronisation correction by **Monte Carlo models**
- More complete than NLO analyses: Data described well over virtually all phase space

Measuring α_s: New NNLO calculations

$\alpha_s(m_{Z^\circ})$ results



Errors: stat. / exp.+had.+scale

- More complete than NLO+NLLA analyses:
  - renormalisation scale uncertainty reduced
  - scatter from different variables reduced
- Result from JADE, NNLO+NLLA:

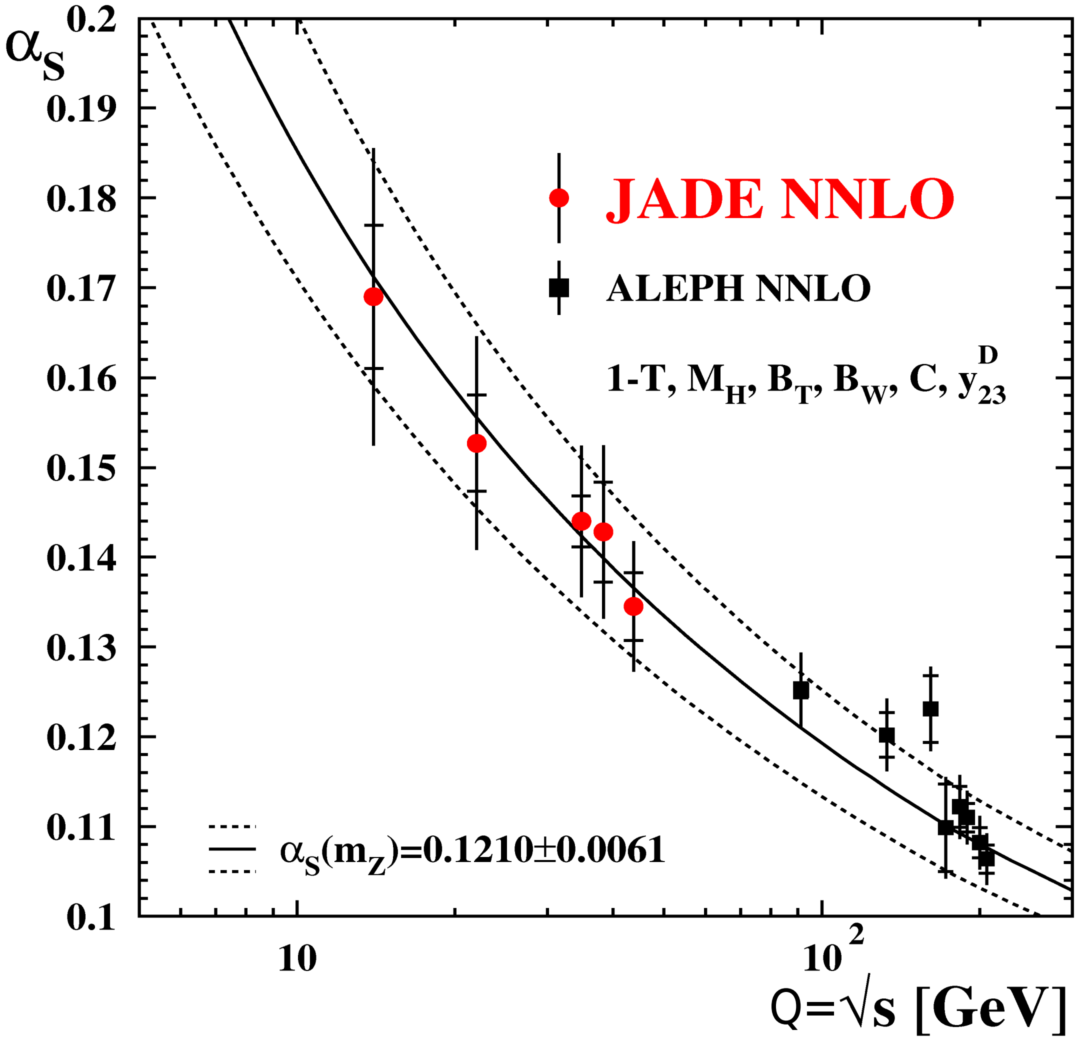
$$\boxed{\alpha_S(M_{Z^\circ})=0.1172\pm0.0051}$$

4% precision, among the best measurements

Measuring α_S: New NNLO calculations

Running $\alpha_S(Q)$ result

from event shape combination



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Running of α_S confirmed strongly in the JADE range 14—44 GeV.

NNLO: $\alpha_s(m_{Z^\circ})=0.1210\pm0.0061$(tot.)

NNLO+NLLA: $\alpha_s(m_{Z^\circ})=0.1172\pm0.0051$(tot.)

Conclusion

- Running of $\alpha_S(Q)$ confirmed strongly in the JADE energy range
- $\alpha_s(m_{Z^\circ})=0.1172\pm0.0051(\mathrm{tot.})$ from NNLO+NLLA at 14-44 GeV
- Event shape moments reveal shortcomings of the NLO calculations
- Outlook:
  - OPAL NNLO analysis in progress
  - Moments NNLO analysis would be interesting
  - Re-analyses of data taken at the JADE and OPAL experiment have huge potential
  - QCD precisely studied in e^+e^- important for LHC