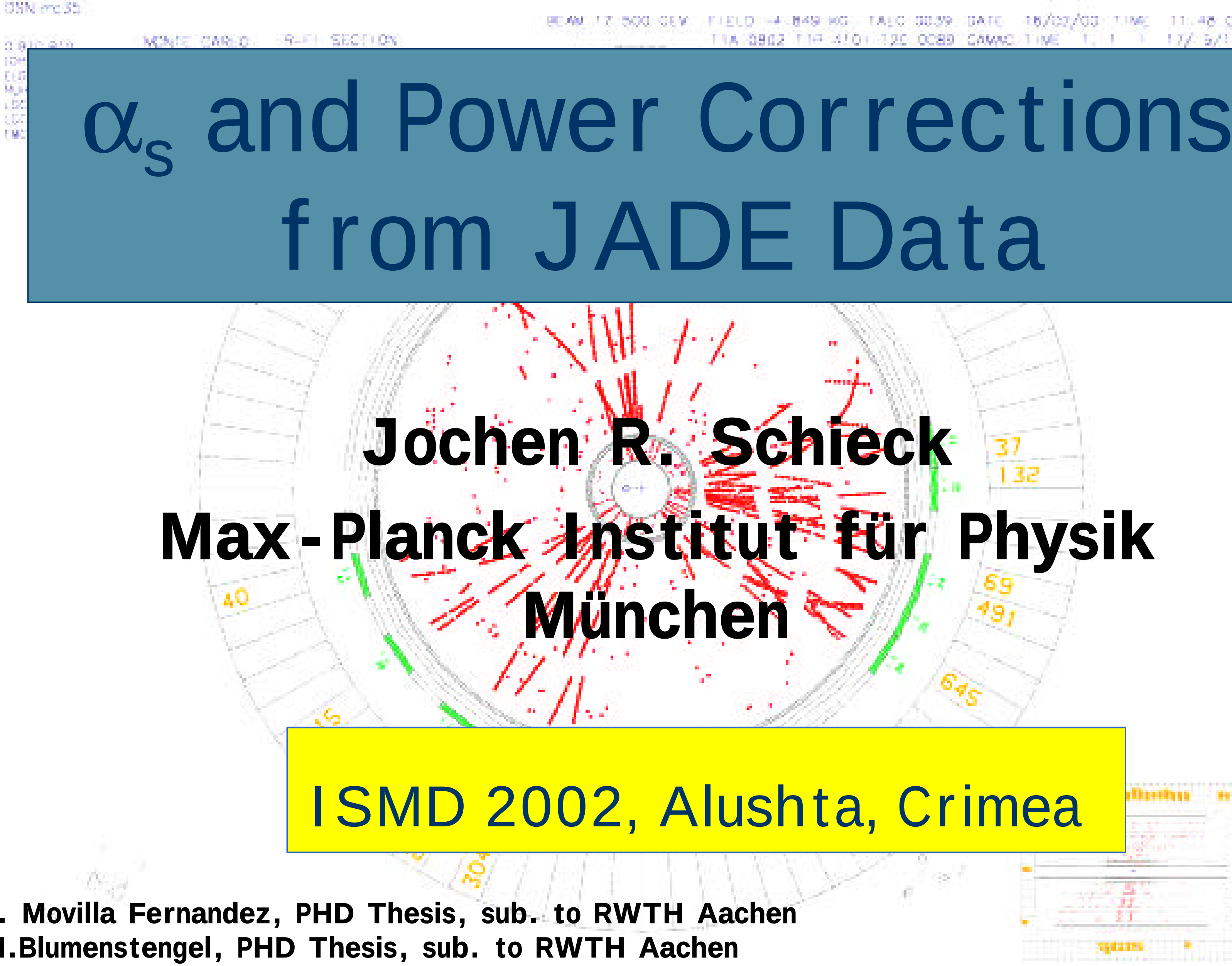


α_s and Power Corrections from JADE Data

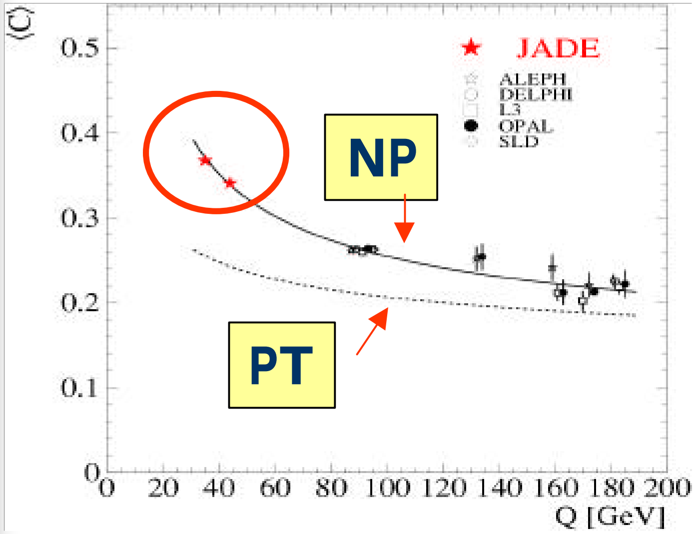
Jochen R. Schieck

Max-Planck Institut für Physik München

ISMD 2002, Alushta, Crimea

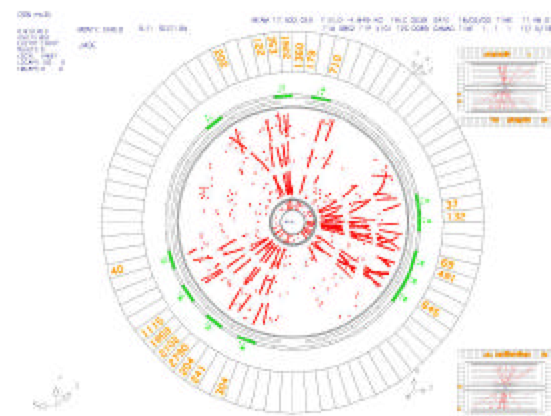
P. Movilla Fernandez, PHD Thesis, sub. to RWTH Aachen
M.Blumenstengel, PHD Thesis, sub. to RWTH Aachen
Phys.Lett.B517(2001)37

Motivation



e^+e^- data at low CME provide large leverage for QCD tests

•pertubative effects ~ 1/ln Q
•non pertubative effects ~ 1/Q

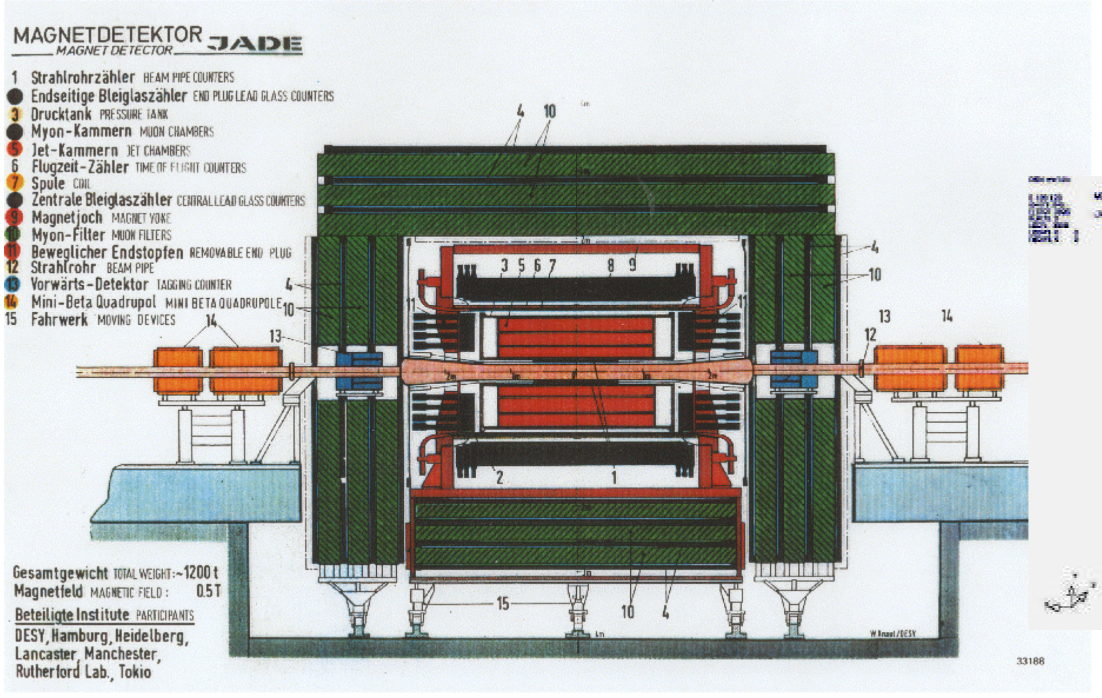


•previous measurements at low energy have large (theoretical) errors
•since LEP/SLC era new theoretical input (NLLA+O(α_s^2) predictions)

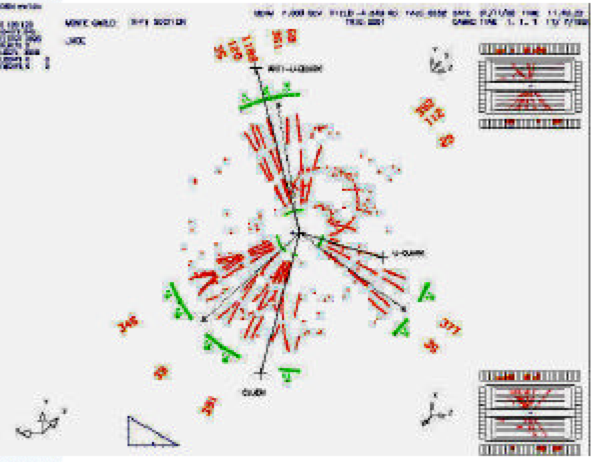
➢**reduced theoretical uncertainties**

(smaller dependence on x_μ)

The JADE Detector



MC event



NEW: original JADE simulation software reactivated
(before only CME = 35 and 44 GeV available)

MC: Pythia/Jetset (LEP & JADE tuned versions), Ariadne, Herwig, Cojets

α_s from e^+e^- Event Shapes at 14-44 GeV

Event Shapes

- Thrust $(1-T)$
- Heavy Jet Mass (M_H)
- Jet Broadening $(B_T,B_W)^*$
- C Parameter*
- Differential 2-jet rate y_{23}^* (Durham scheme)

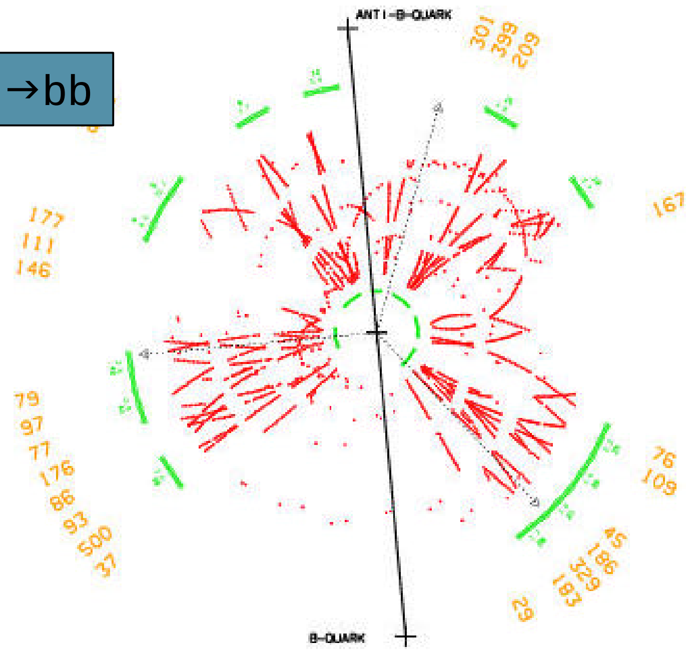
- infrared and collinear safe quantities
- resummable in all orders $\alpha_s \ln(1/F)$

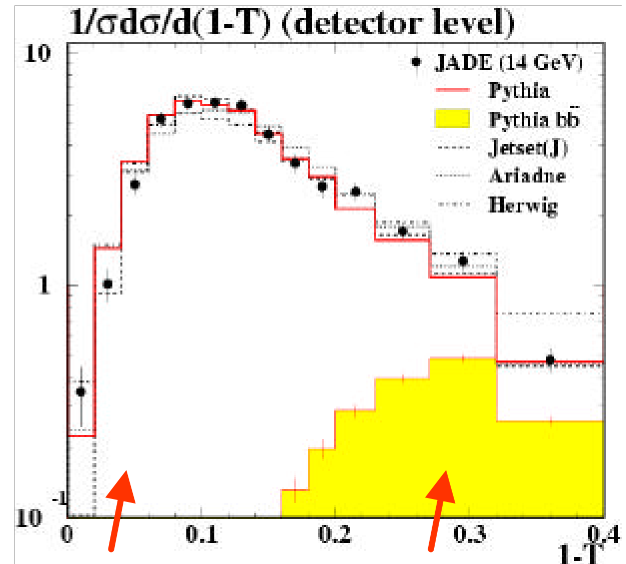
$F=1-T, C, M_H, \ldots$

*) Event Shape variables only used after shutdown of PETRA

bb-Corrections

$e^+e^- \rightarrow bb$



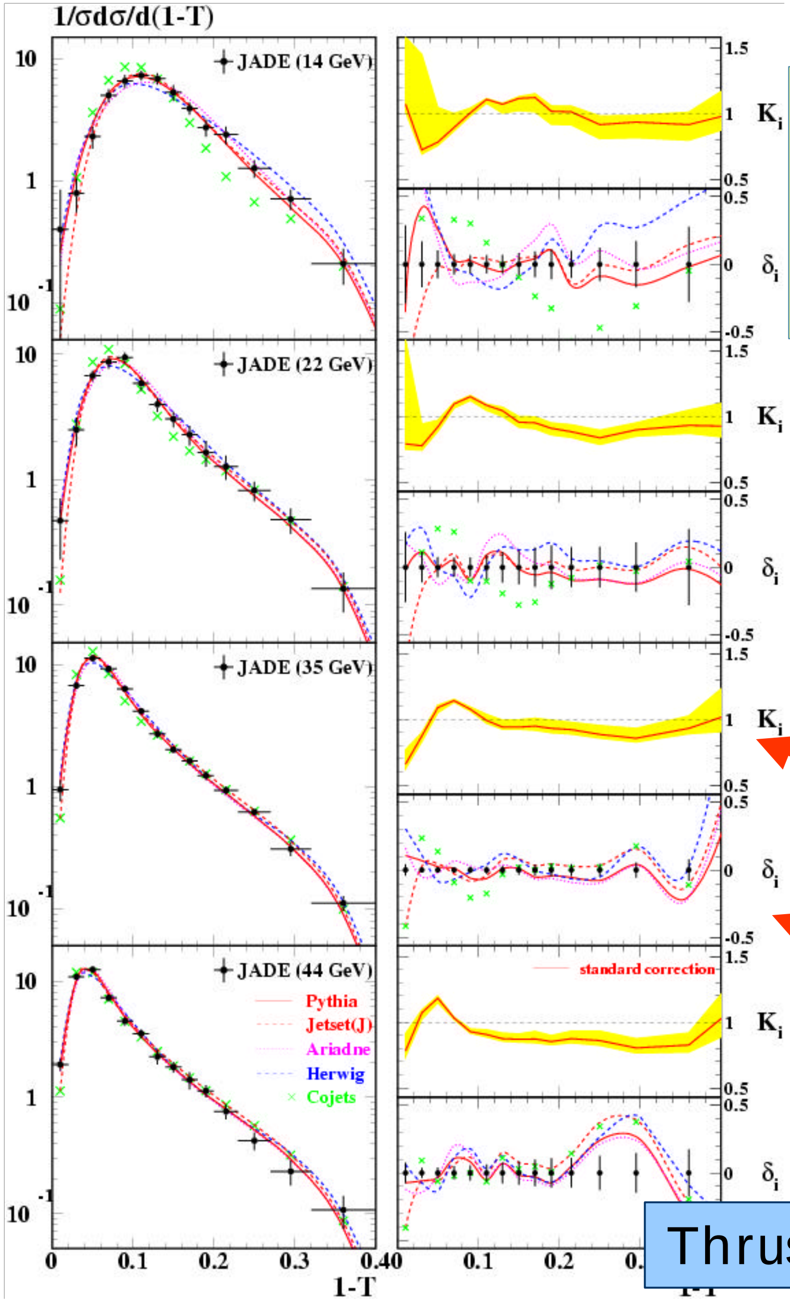


2-jet region

bb events

- bb events fakes events with gluon radiation (electro weak decay)
  - ➢subtraction at detector level
- Correction for detector effects
  - ➢bin-by-bin unfolding $K_i = MC_i^{had} / MC_i^{det}$ using udsc sample

Detector Correction



Thrust (1-T)

Comparison with different hadronisation models

detector corrections

normalized deviations from model predictions

Determination of α_s

•O(α_s^2) calculations, (3 jet region):

(used for previous analysis)

$$\frac{dR}{dF} = \frac{1}{s_0}\frac{ds}{dF} = \frac{dA(F)}{dF}\frac{a_s(\mu)}{2p} + \frac{dB(F)}{dF}\left(\frac{a_s(\mu)}{2p}\right)^2 + O\left(\left(\frac{a_s(\mu)}{2p}\right)^3\right)$$

•no good description for F →0 (divergent)

•NLLA calculations (resums soft gluon contribution, 2 jets):

$$R(F) = \int_0^F dF' \frac{1}{s_0}\frac{ds(F')}{dF'} = C(a_s)e^{G(a_s,L)} + D(a_s,L)$$

$$L = \ln(1/F)$$

$$R(F) = (1 + C_1 a_s + C_2 a_s^2)e^{Lg_1(a_s L) + g_2(a_s L)}$$

Determination of α_s

$O(\alpha_s^2)$ + NLLA matching:

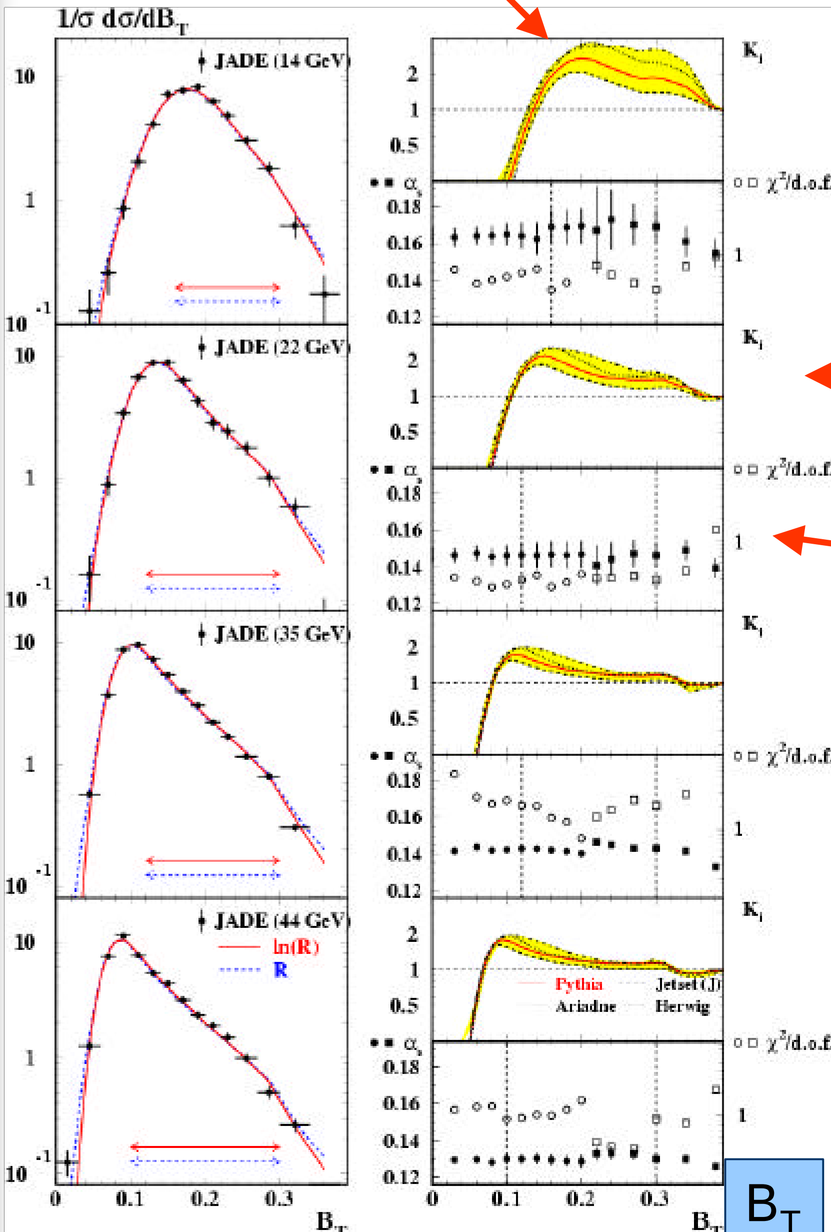
$$\ln(R(F)) = Lg_1(\alpha_s L) + g_2(\alpha_s L) - (G_{11}L + G_{12}L^2)\alpha_s/2\pi - (G_{22}L^2 + G_{23}L^3)(\alpha_s/2\pi)^2$$
$$+ A(F)\frac{\alpha_s}{2\pi} + (B(F) - \frac{1}{2}A(F)^2)(\frac{\alpha_s}{2\pi})^2$$

- Fit perturbative predictions with scale factor x_μ=1 and α_s as free parameter

- correct parton distribution to hadron distribution
  - bin-by-bin hadronisation correction for R(F) with Pythia

Measurement Fits

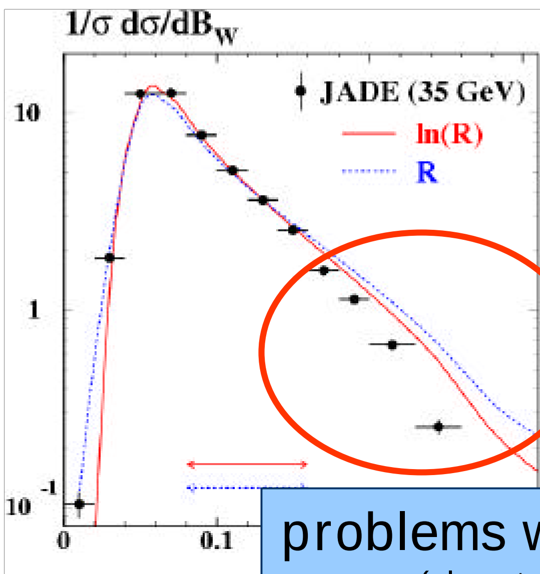
large hadron correction for CME = 14 GeV (50-100%)



B_T

correction from parton → hadron

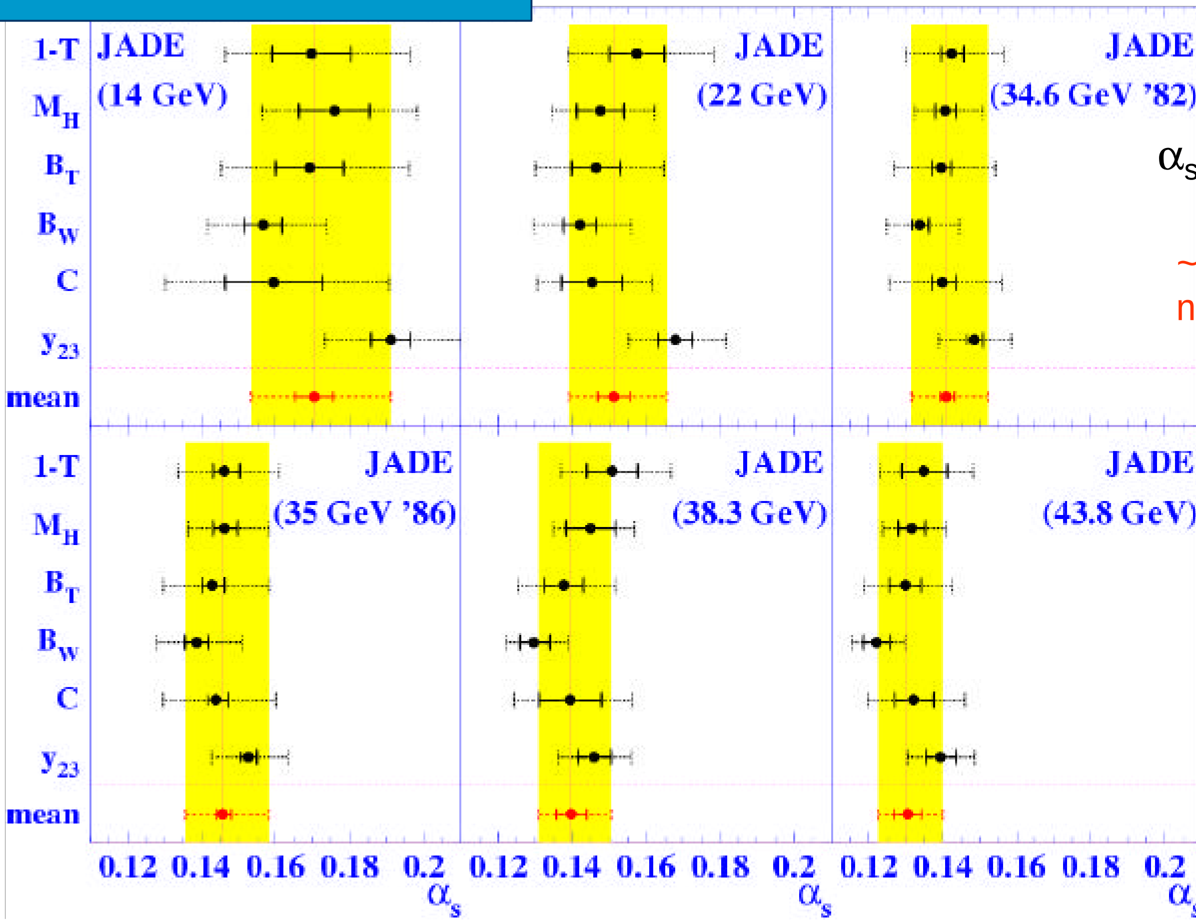
α_s and χ^2 dependency of fit range



problems with B_W
(also at LEP visible!)

α_s Results

PRELIMINARY



α_s (34.6) = 0.12±0.01±0.01
Phys.Rep.**148**(1987)67

~30% smaller error with new theoretical calculations

Dominant errors:

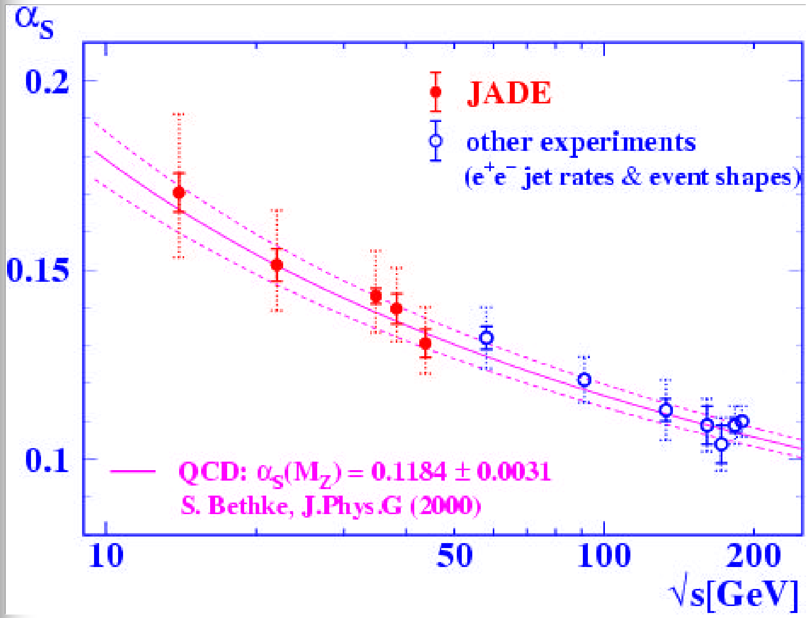
- renormalisation scale
- hadronisation uncertainties

x_μ dependency significantly reduced w.r.t $O(\alpha_s^2)$ calculations

α_s Evolution

$$a_s(Q) = \frac{1}{b_0 L} - \frac{b_1 \ln L}{b_0^3 L^2} + \frac{1}{b_0^3 L^3}\left[\frac{b_1^2}{b_0}(\ln^2 L - \ln L - 1) + \frac{b_2}{b_0}\right]$$

$$L = \ln(Q/\Lambda_{\overline{MS}})^2$$



Fit to 14-44 GeV:

$\alpha_s(M_{Z^\circ})=0.120\pm0.001(\pm0.006)$

$\chi^2=3.1/4$

$P(\chi^2,\text{d.o.f.})=54\%$

Power Corrections

- no correction for hadronisation effects with MC generator necessary
- Dokshitzer-Marchesini-Webber (DMW) structure of power corrections:

$$\langle F \rangle = \langle F \rangle^{PT} + D_F P$$

$$\frac{ds(F)}{dF} = \frac{ds^{PT}(F - D_F P)}{dF}$$

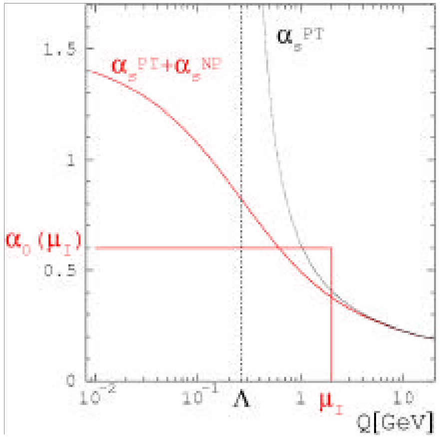
$$D_F = a_F \cdot \ln(1/F) + F_F \quad F = B_T, B_W$$

$$D_F = const. \quad F = 1-T, M_H^2, C$$

$$P = \frac{4C_F}{p^2} M \frac{m_I}{Q}\left[a_0(m_I) - a_s(m_R) - b_0 \frac{a_s^2}{2p}\left(\ln(\frac{m_R}{m_I}) + \frac{K}{b_0} + 1 \right)\right]$$

universal parameter

$$a_0(m_I) \equiv \frac{1}{m_I}\int_0^{m_I} dm\, a_s(m)$$



Fit to Distribution

•global fit of

pQCD + Power Corrections (DMW model)

to overall event shape and mean values data from:

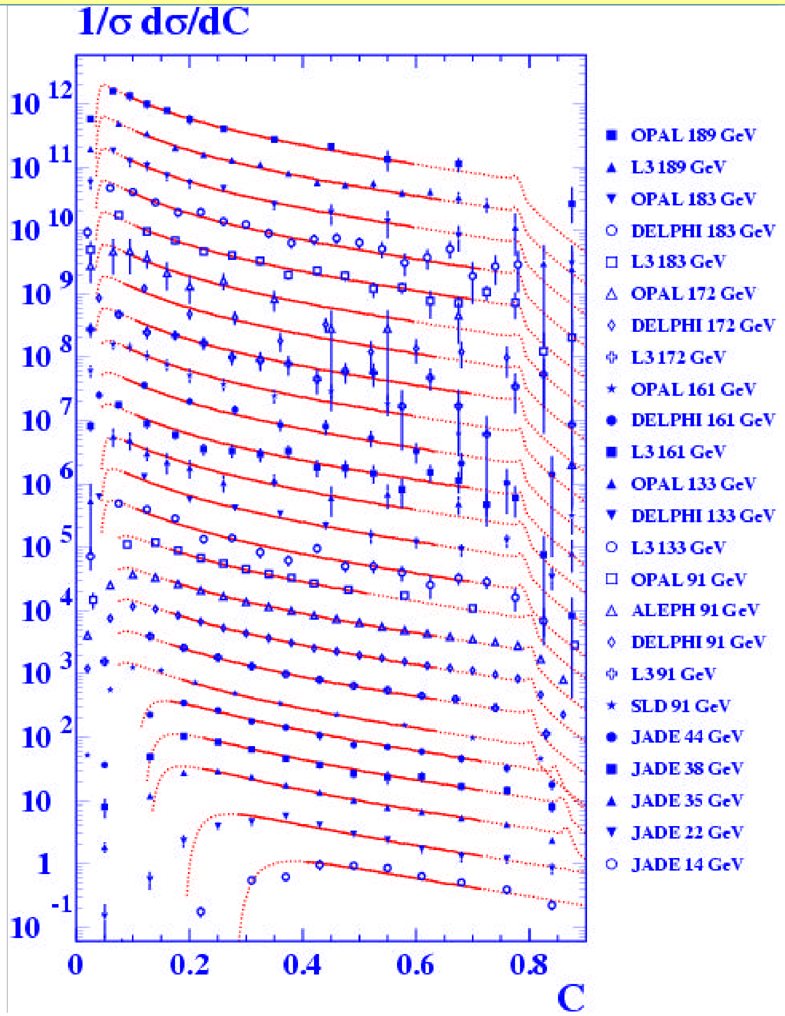
PETRA
PEP
TRISTAN
SLC
LEP

(CME = 14-189 GeV)

2 free fit parameters:

1. α_s strong coupling
2. α_0 universal parameter for all event shapes

α_s,α_0 Fits to Distribution

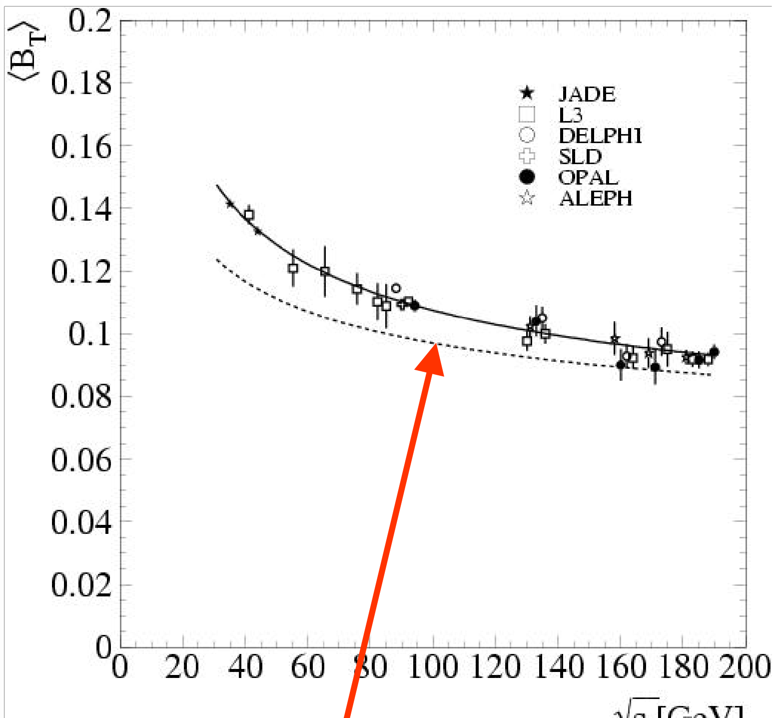


very good fit to data!

χ^2=181/216 d.o.f

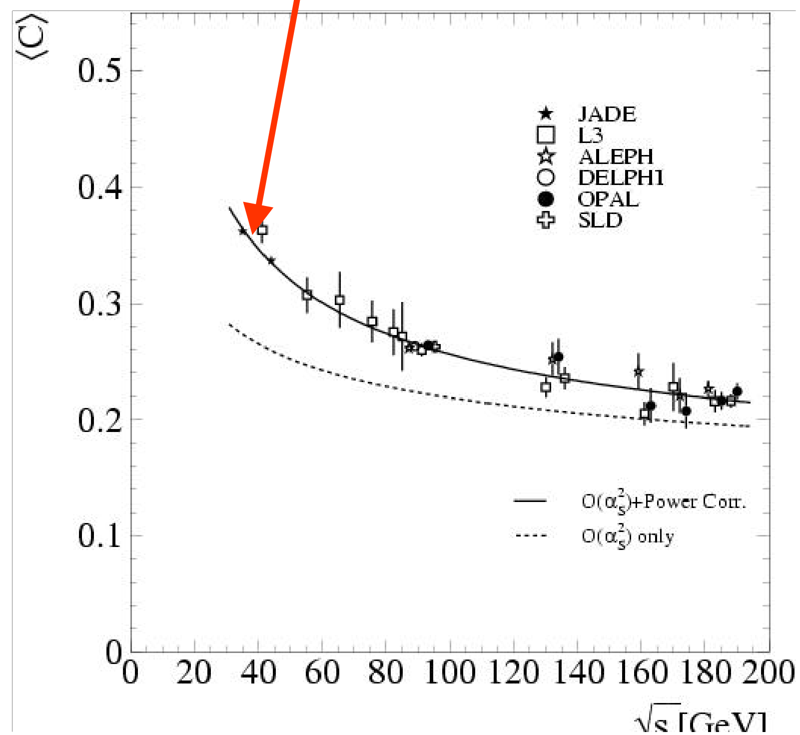
2 parameter fit with α_s,α_0 describes distribution at 13 different energies simultaneously

α_s,α_0 Fits to Mean Values

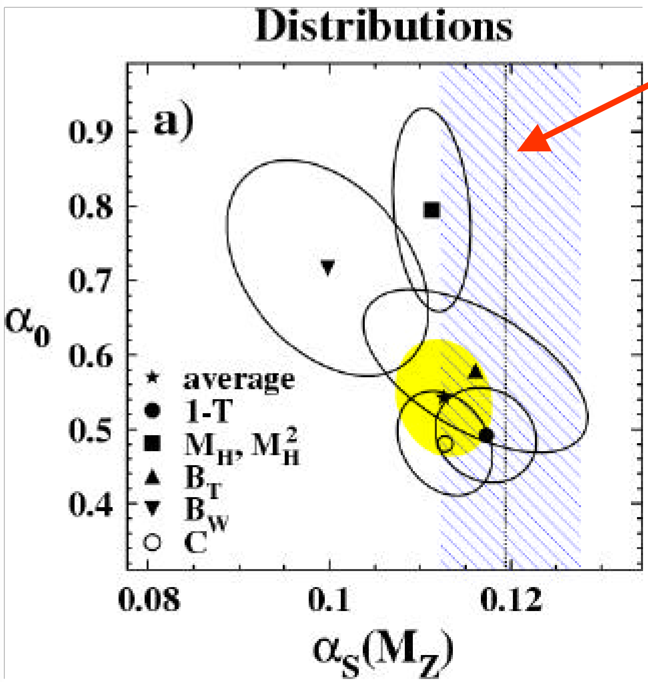


perturbative predictions

perturbative predictions plus power corrections



(α_s,α_0) Fit Results

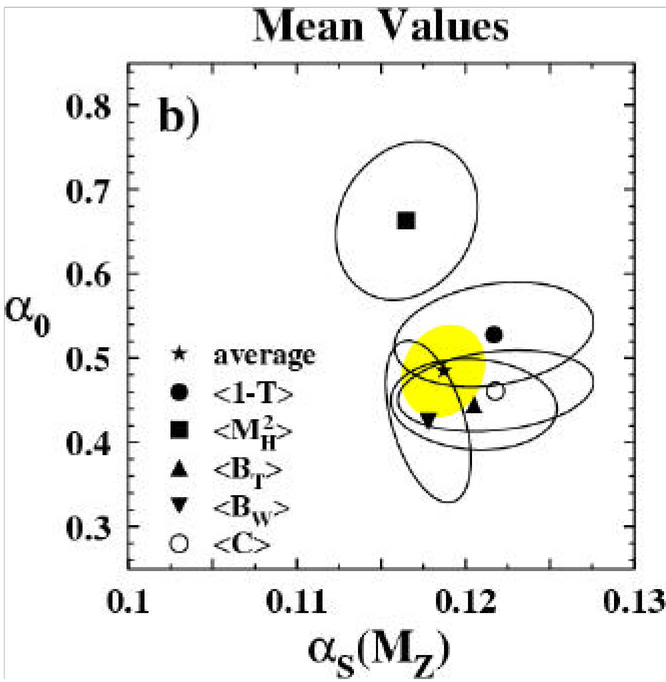


'conventional' analysis

$\rho_{fit}(\alpha_s\text{-}\alpha_0)$

~-80%

(single fit)

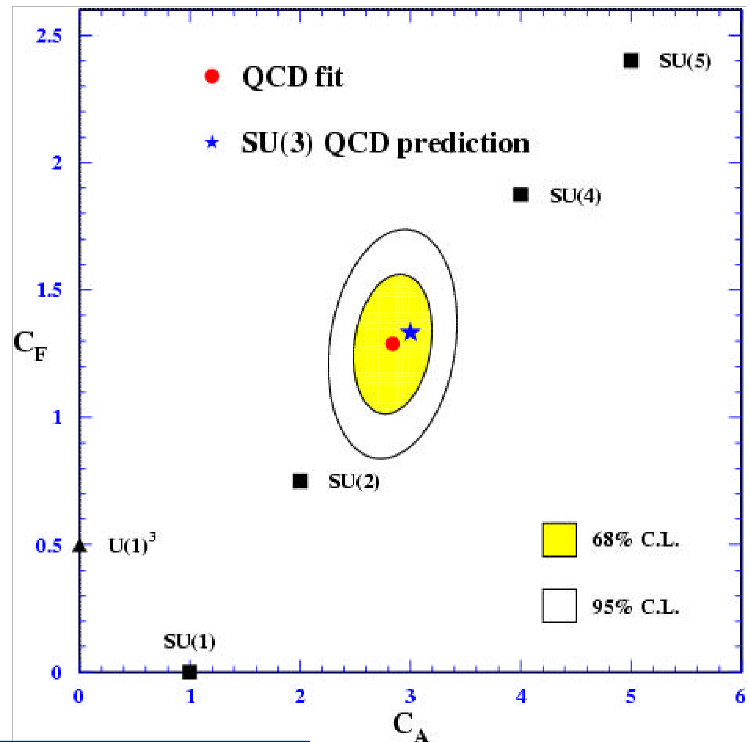


Distribution	Fit	Stat	Exp	Theo
$\alpha_s(M_{Z^\circ})$	0.1126	±0.0005	±0.0037	+0.0044 -0.0030
α_0(2 GeV)	0.542	±0.005	±0.032	+0.084 -0.060

Mean Values	Fit	Stat	Exp	Theo
$\alpha_s(M_{Z^\circ})$	0.1187	±0.0014	±0.0001	+0.0028 -0.0015
α_0(2 GeV)	0.485	±0.013	±0.001	+0.065 -0.043

Color Structure from Event Shapes

- **Perturbative Prediction**
  - $A = A(C_F)$
  - $B = B(C_A, C_F, n_f)$
  - $NLLA = NLLA(C_A, C_F, n_f)$
- **Power Corrections**
  - $P = P(C_A, C_F, n_f)$
  - $M = M(C_A, n_f)$
  - $D_F = D_F(C_A, C_F, n_f)$



$C_A = 2.84 \pm 0.24$ (QCD:3)
$C_F = 1.29 \pm 0.18$ (QCD:4/3)

$r_{fit}(C_A - C_F) = 0.19$

(competitive with 4 jet angular analysis)

σ_L and σ_T with JADE

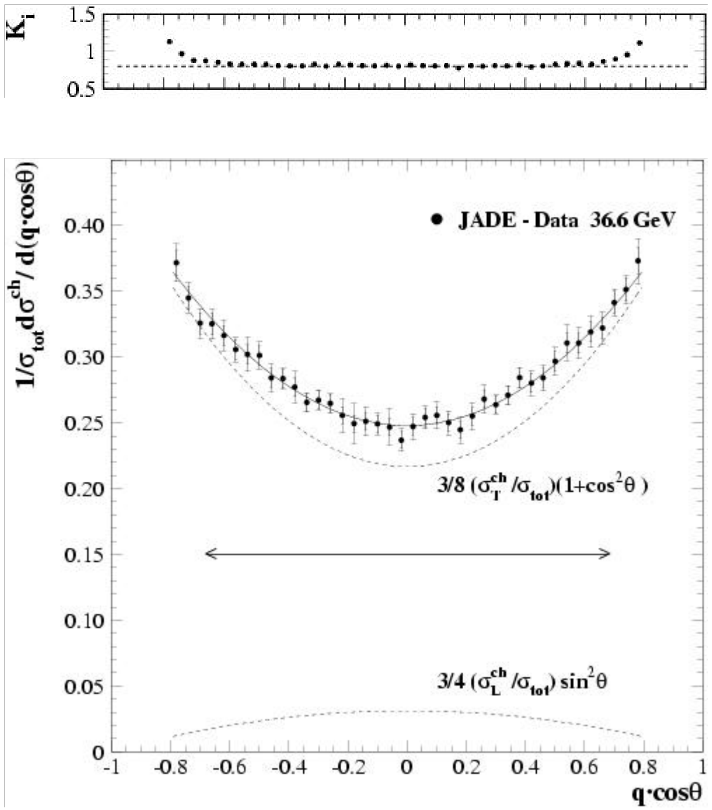
$$\frac{1}{\sigma}\frac{d\sigma}{d(q\cdot\cos\theta)} = \frac{3}{8}(1+\cos^2\theta)\frac{\sigma_T^{ch}}{\sigma_{tot}} + \frac{3}{4}(\sin^2\theta)\frac{\sigma_L^{ch}}{\sigma_{tot}}$$

(no quark-antiquark separation
→ no asymmetric term)

σ_L~0 at quark production vertex

σ_L<>0

→ contribution from gluon radiation



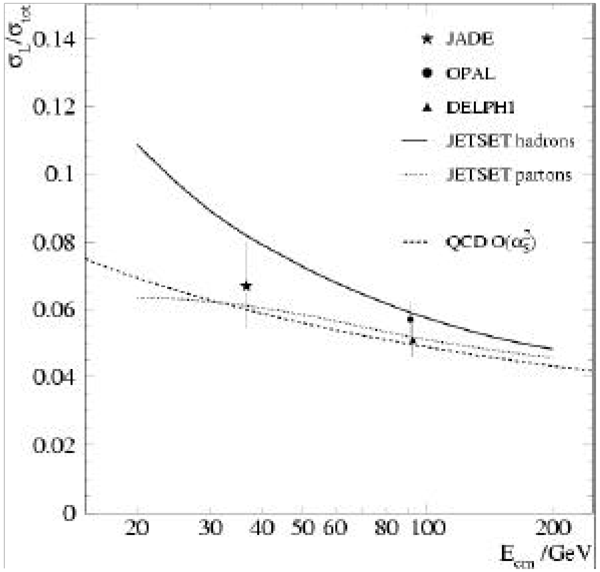
Measurement of σ_L and σ_T

$\sigma_L / \sigma_{tot} = 0.067 \pm 0.013$

$$\left(\frac{s_L}{s_{tot}}\right) = \frac{a_s}{p} + 8.444\left(\frac{a_s}{p}\right)^2$$

$\alpha_s(36.6\ \text{GeV}) = 0.150 \pm 0.02$

$\alpha_s(M_{Z^\circ}) = 0.127 \pm 0.018$



Power Correction:

$$d_{PC} = \frac{8M}{3p}\frac{m_I}{Q}\left(a_0(m_I) - a_S\right)$$

$\alpha_s(M_{Z^\circ}) = 0.126 \pm 0.025$

$\alpha_0(\mu_i) = 0.3 \pm 0.3$

Measurement of ln(1/x) Distribution

$x=2p/s^{1/2}$

Fit to distribution (skewed gaussian):

$$F_q(x,Y) = \frac{N(Y)}{s\sqrt{2p}} \cdot \exp\left(\frac{k}{8} - \frac{sd}{2} - \frac{(2+k)d^2}{4} + \frac{sd^3}{6} + \frac{kd^4}{24}\right)$$

$Y=\ln(s^{1/2}/2\Lambda_{eff})$

N(Y): normalization related to charged multiplicity

$<\zeta>$=function of Y + O(1)

$\delta=(\zeta-<\zeta>)/\sigma$

σ:width

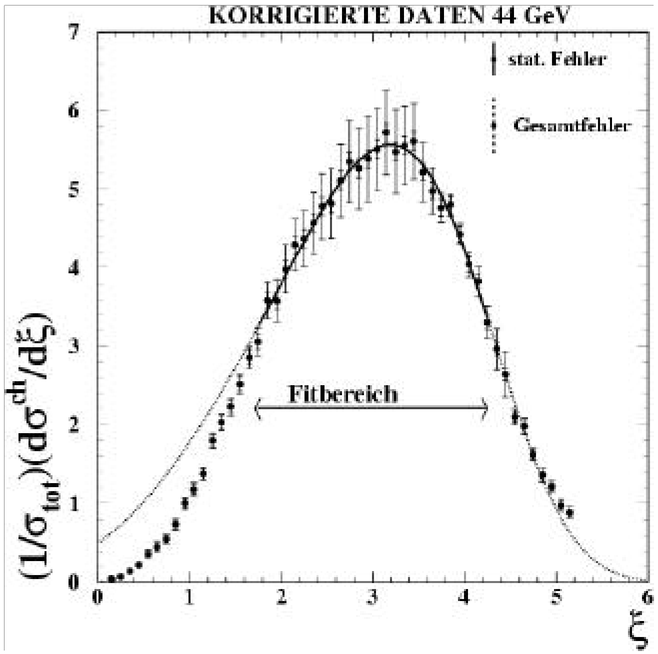
s: skewness

k: kurtosis

ζ^0: peak position

} Y dependent!

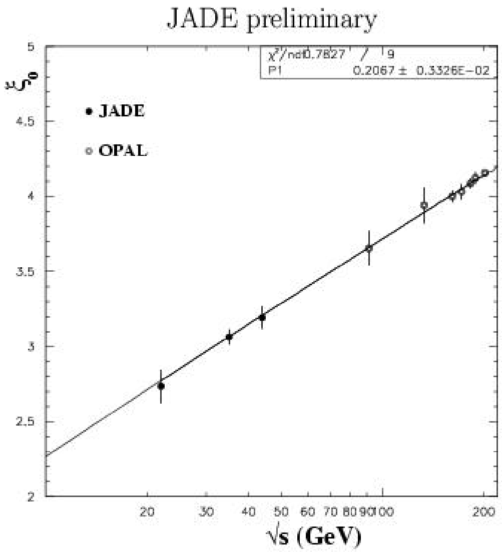
$\zeta^0-<\zeta>=(11+2N_f)/(32*9C_A)$

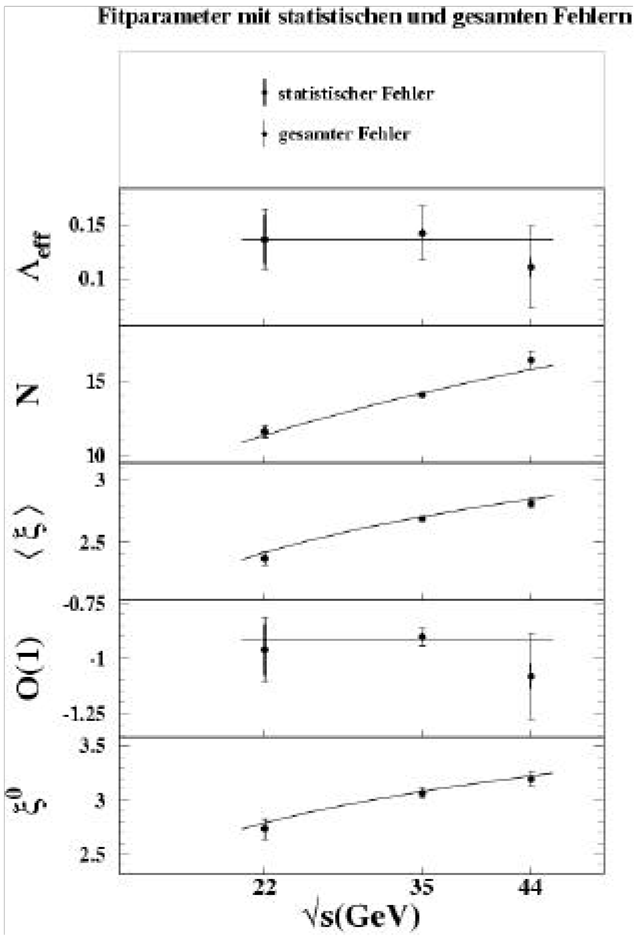


Measurement of ln(1/x) Distribution

Fit NLLA (Fong,Webber):

Λ_{eff},N and <ζ>,ζ^0or O(1)





<ζ> ,ζ^0 and N depend on $s^{1/2}$

Λ_{eff} and O(1) constant

Conclusion (I)

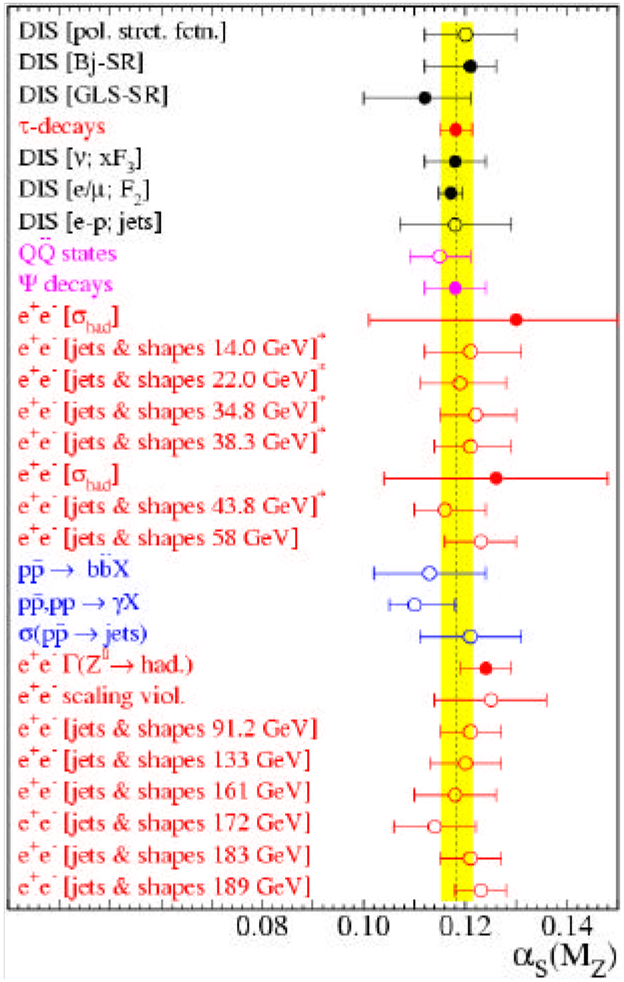
- $O(\alpha_s^2)$ + NLLA calculation first time applied to PETRA data

$\alpha_s(M_{Z^\circ})=0.1194^{+0.0083}_{-0.0070)}$ (PETRA)

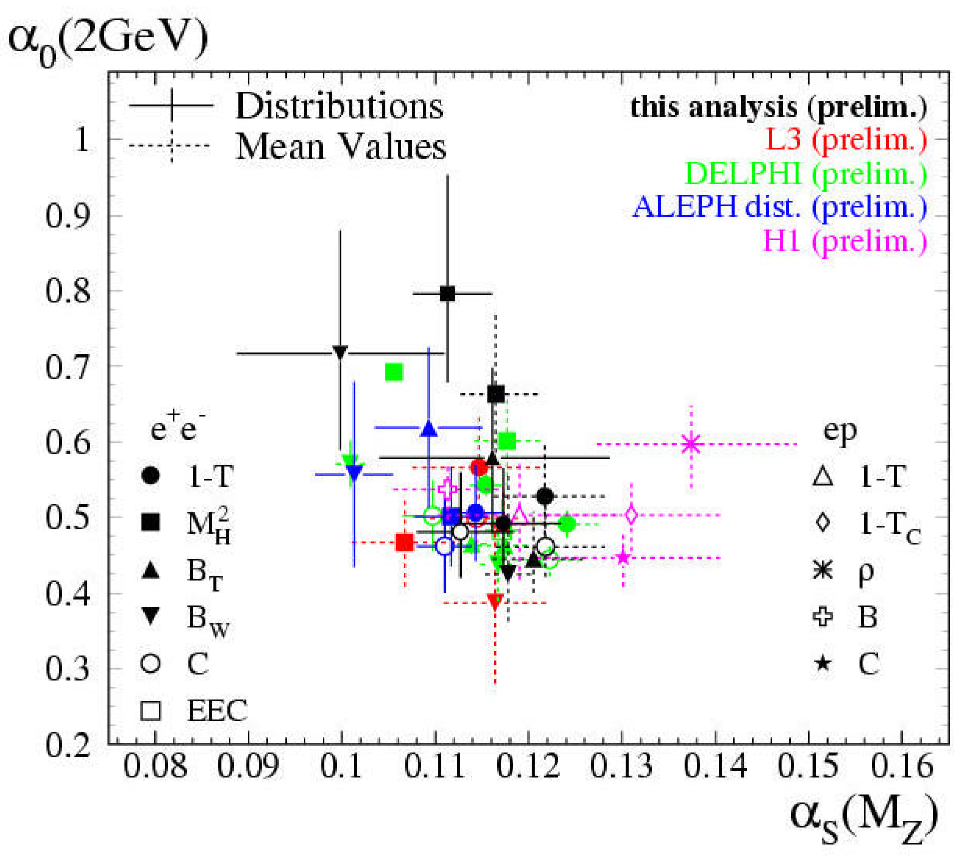
$\alpha_s(M_{Z^\circ})=0.121\pm0.006$ (LEP+SLC)

$\alpha_s(M_{Z^\circ})=0.120\pm0.007$(LEP2)

- consistent with other measurement and methods



Conclusion (I I)



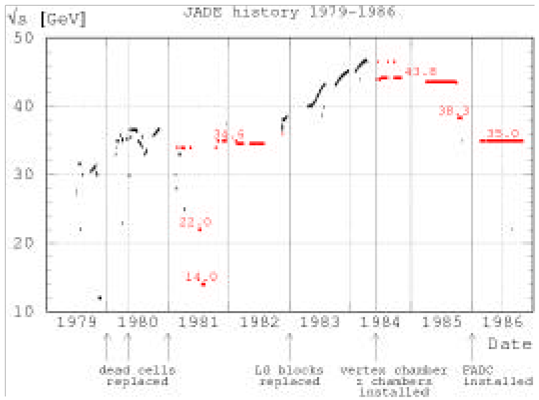
- universality of α_0 confirmed within 20%
- SU(3) structure of QCD confirmed

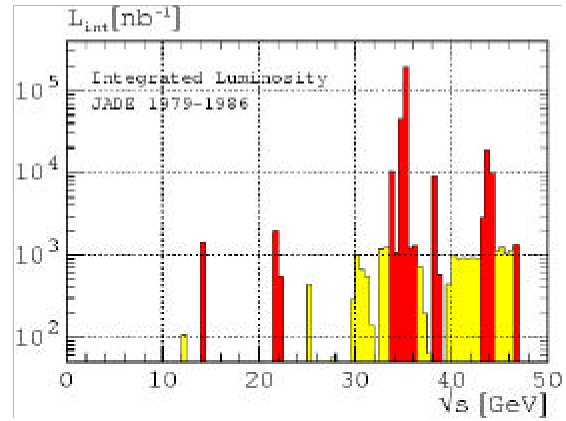
$\alpha_s(M_{Z^\circ})=0.1175^{+0.0031}_{-0.0021}$

$\alpha_0(2\text{GeV})=0.503^{+0.066}_{-0.045}$

- measurement of α_s with σ_L / σ_{tot}
- energy dependency of ln(1/x) spectra

JADE at Petra (1979-1986)





CME range (GeV)	Data taking period	Luminosity (pb^{-1})	<CME> (GeV)	MH events
14.0	07-08/1981	1.46	14.0	1734
22.0	06-07/1981	2.41	22.0	1390
33.8-36.0	02/1981-08/1982	61.7	34.6	14372
35.0	02-06/1986	92.3	35.0	20925
38.3	10-11/1981	8.28	38.3	1587
43.4-46.6	06/1984-10/1985	28.8	43.8	3940

LEP @ 91 GeV:
34 pb^{-1}
1.5 M events
(OPAL)

α_s Results

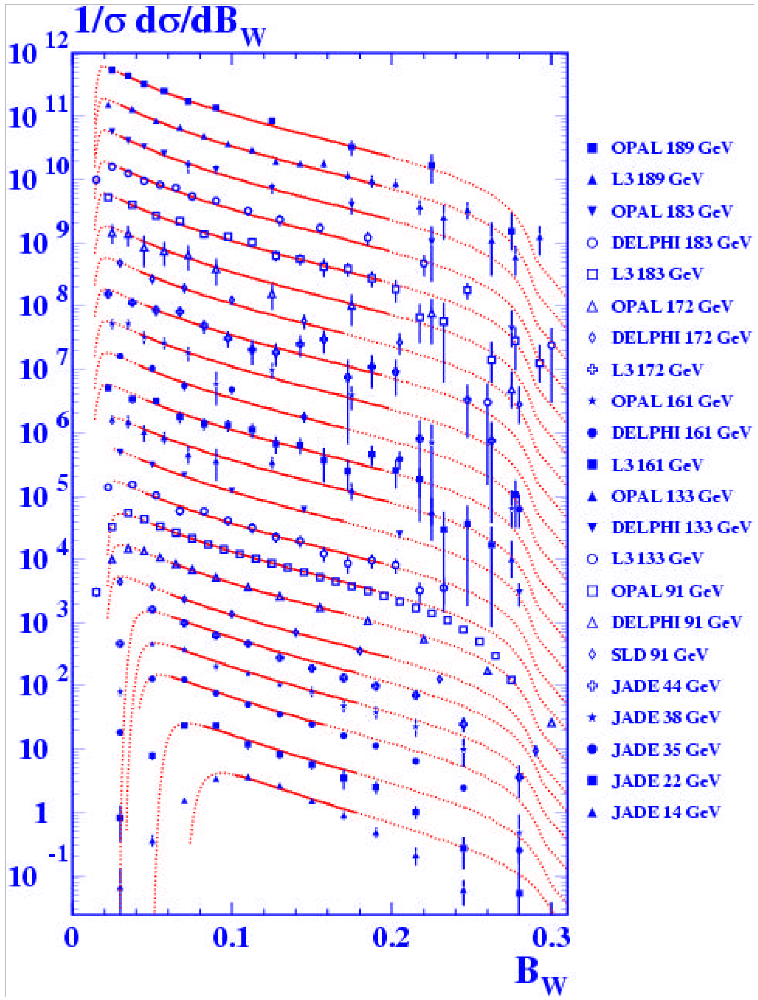
CME (GeV)	a_s(CME)	Fit error	Exp.	Hadr.	Higher order	Total
14.0	0.1704	±0.0051		+0.0141 -0.0136	+0.0143 -0.0091	+0.0206 -0.0171
22.0	0.1513	±0.0043		±0.0101	+0.0101 -0.0065	+0.0144 -0.0121
34.6('82)	0.1409	±0.0012	±0.0017	±0.0071	+0.0086 -0.0057	+0.0114 -0.0121
35.0('86)	0.1457	±0.0011	±0.0020	±0.0076	+0.0096 -0.0064	+0.0125 -0.0101
38.3	0.1397	±0.0031	±0.0026	±0.0054	+0.0084 -0.0056	+0.0108 -0.0087
43.8	0.1306	±0.0019	±0.0032	±0.0056	+0.0068 -0.0044	+0.0096 -0.0080

α_s (34.6) = 0.12±0.01±0.01

Phys.Rep.**148**(1987)67

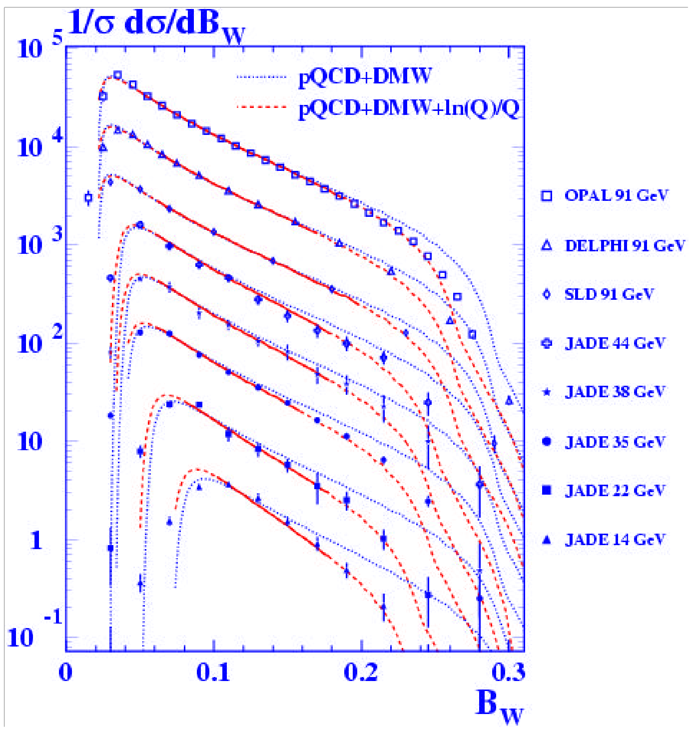
~30% smaller error with new theoretical calculations

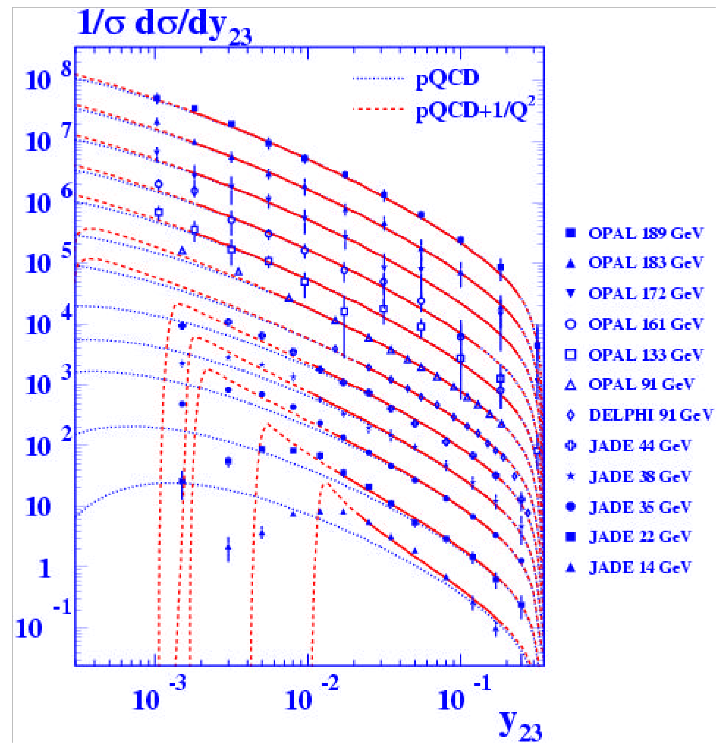
α_s,α_0 Fits to Distribution



problems with BW also visible at 3 jet region

PC – Higher Order Contributions





Log. Enhancement ~ lnQ/Q
yields better description of data

$1/Q^2$ corrections for y_{23}
Fit: $pQCD+A_{10}/Q+A_{20}/Q^2$

Comparison: MC Correction - PC