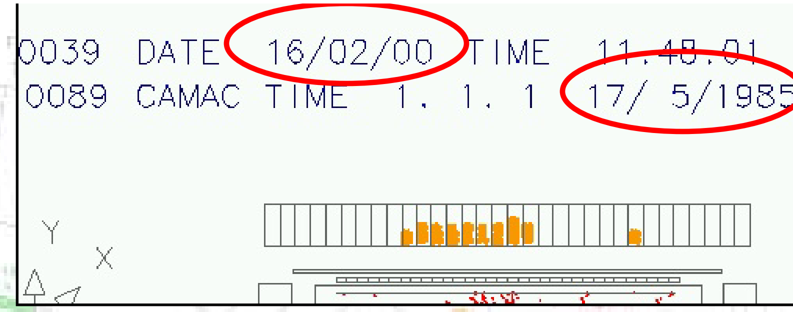


JADE Analysis in the new Millenium

Jochen Schieck

Max-Planck-Institut für Physik, München

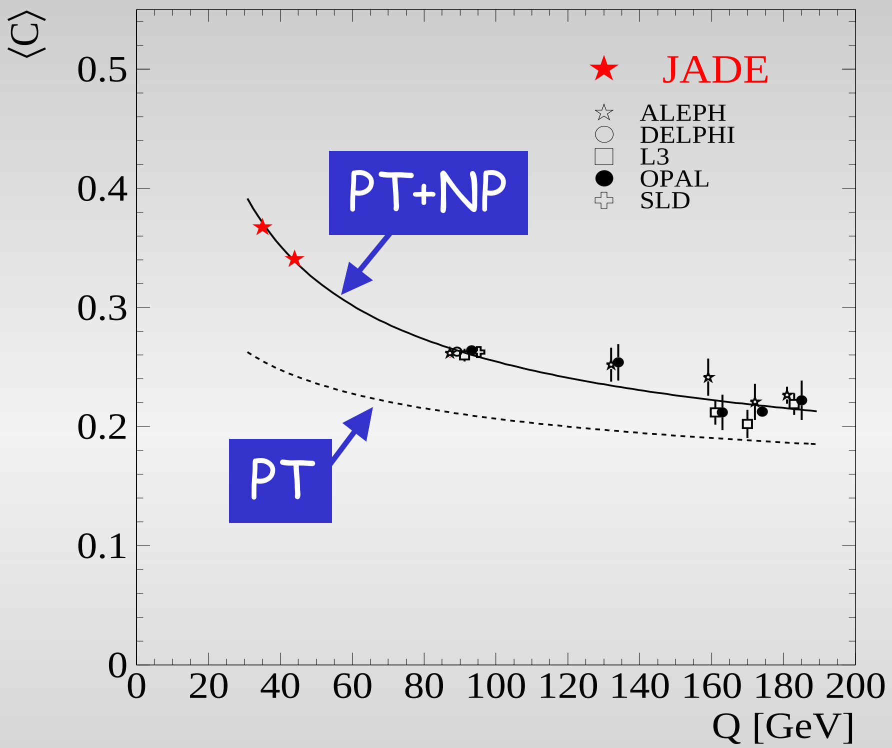
P. Movilla Fernandez, PHD Thesis, RWTH Aachen
M.Blumenstengel, PHD Thesis, RWTH Aachen
Phys.Lett.B517(2001)37
Eur.Phys.J.C21(2001)199
Eur.Phys.J.C22(2001)1
Eur.Phys.J.C1(1998)461

Motivation for Reanalysis

analysis of JADE data provides access to QCD effects at low energy scales

large leverage for QCD measurements at small √s

PT effects ~ 1/log(Q)
NP effects ~ 1/Q

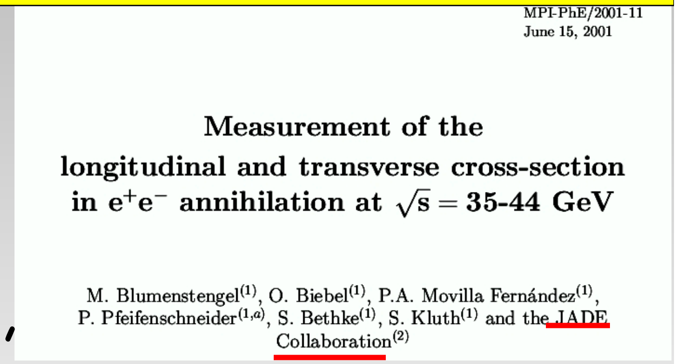


- JADE provides unique contribution for the energy range between 14 and 44 GeV!
- analysis using FSR-Z^0 events O(500) / energy point
(final state radiation)

Outline of the Talk

- the JADE experiment at PETRA
- resurrection of data and software
- status of QCD at the end of PETRA
- latest results from QCD analysis with JADE-Data
  - measurement of α_s with event shapes using resummed calculations
  - power corrections and hadronisation
  - longitudinal and transversal cross-section
  - soft-gluon interference effects

The JADE Revival Group



MPI-PhE/2001-11
June 15, 2001

Measurement of the longitudinal and transverse cross-section in e^+e^- annihilation at $\sqrt{s} = 35$-44 GeV

M. Blumenstengel[1], O. Biebel[1], P.A. Movilla Fernández[1], P. Pfeifenschneider[1,a], S. Bethke[1], S. Kluth[1] and the JADE Collaboration[2]

- RWTH Aachen, MPI München, DESY

  S.Bethke, O.Biebel, M. Blumenstengel,

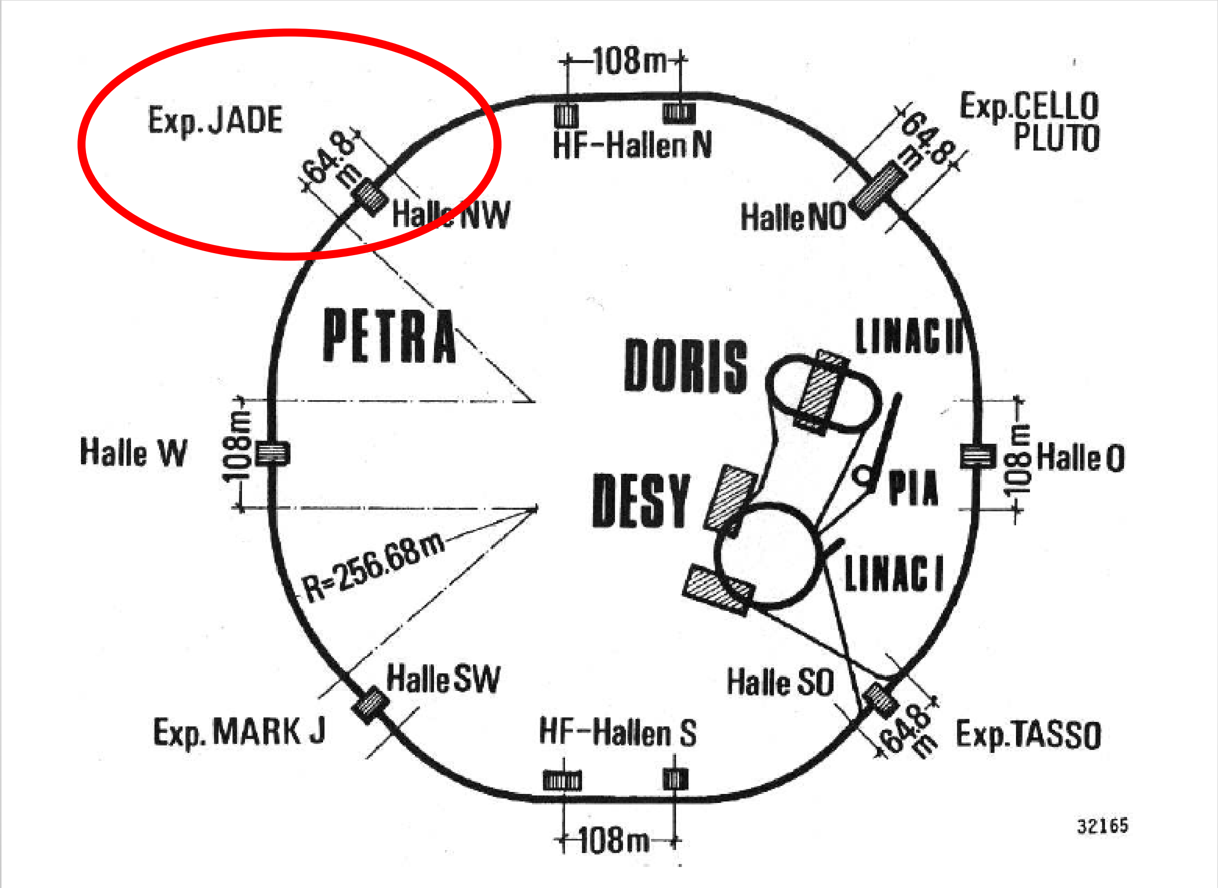
  S. Kluth, P.A. Movilla Fernandez, C. Pahl,

  P. Pfeifenschneider, J.E. Olsson and JS

- since 1998 more than 20 publications and conference contributions based on/involving reanalysed JADE data
- new JADE results have been considered by various QCD theory groups and publications from LEP collaborations

The PETRA e^+e^- Storage Ring

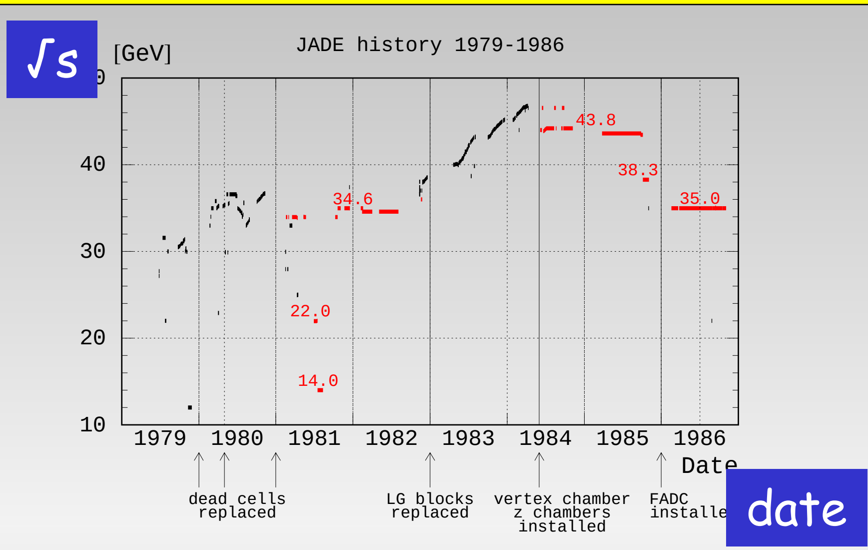
Physics at PETRA from 1979-1986

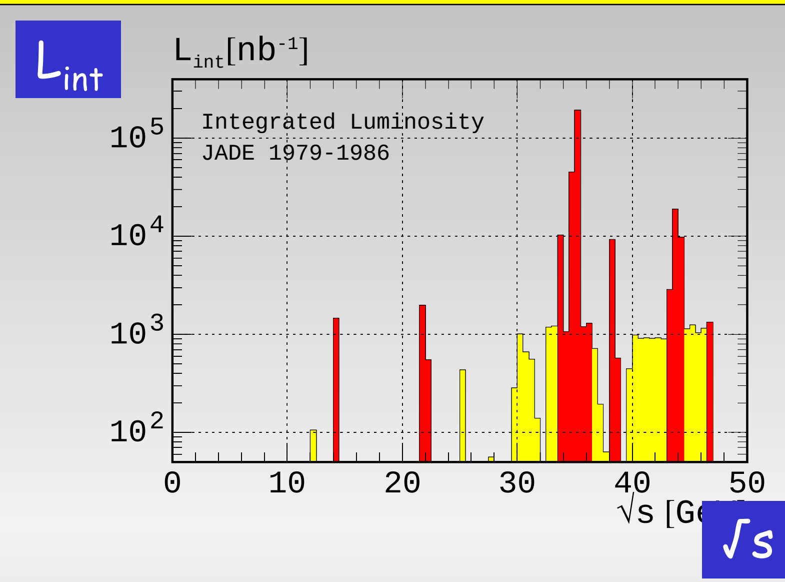


- largest e^+e^- accelerator at that time
- luminosity ~ 24x 10^{30} /cm^2 s^1 (= 26 hadronic events/hour)

(hadronic cross section ~ 0.3 nb)

Data Collected at JADE





fixed energy runs and scan periods for t-quark search

CME range (GeV)	Data taking period	Luminosity (pb^{-1})	√s (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

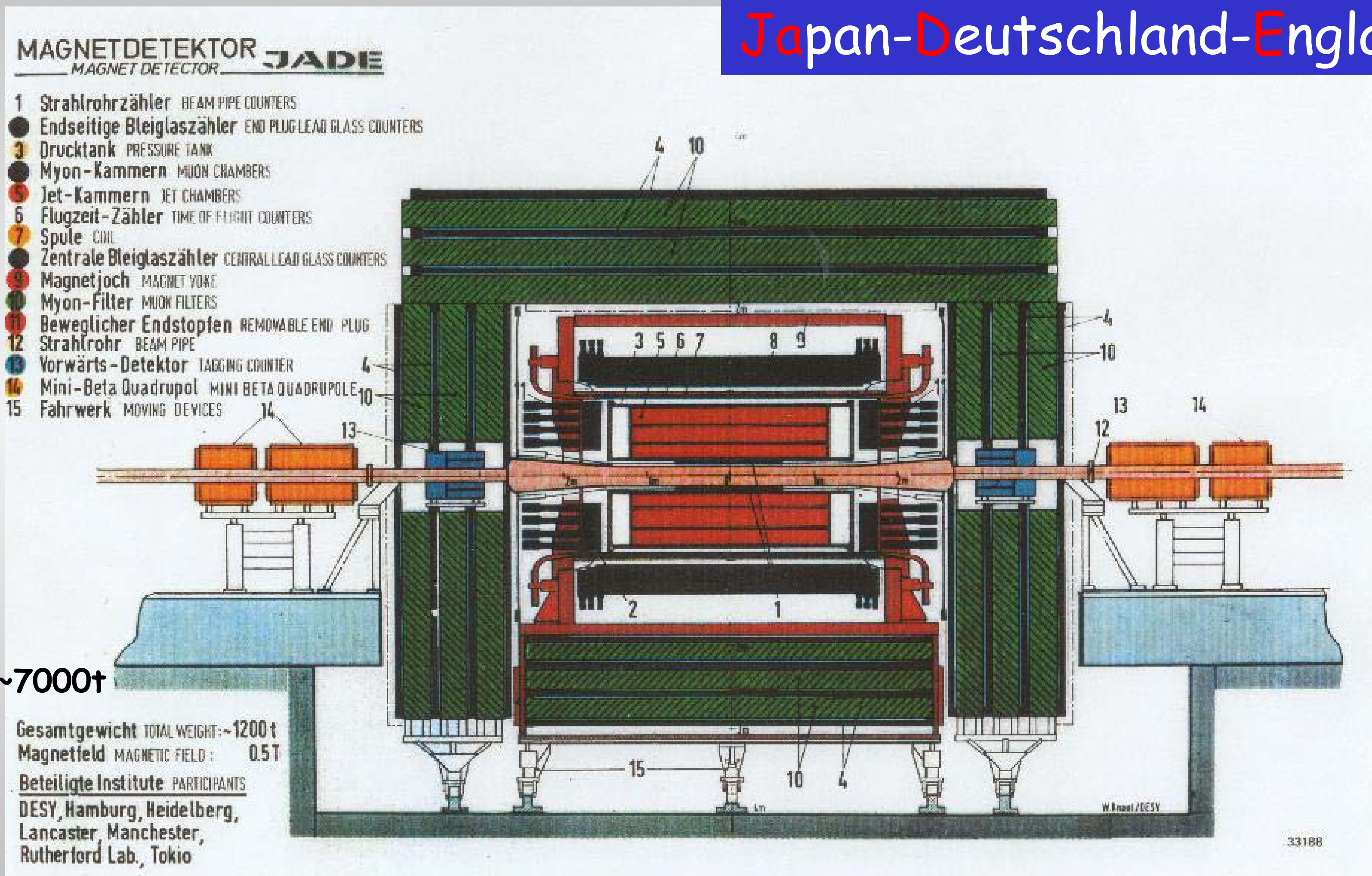
LEP (OPAL): 330000

Zeit. fur Phys.C 59 (1993) 1-19

- 216 pb-1
- 43100 multihadrons

The JADE Experiment

Japan-Deutschland-England



ATLAS~7000t

concept similar to the OPAL detector

Resurrection of Data and Software

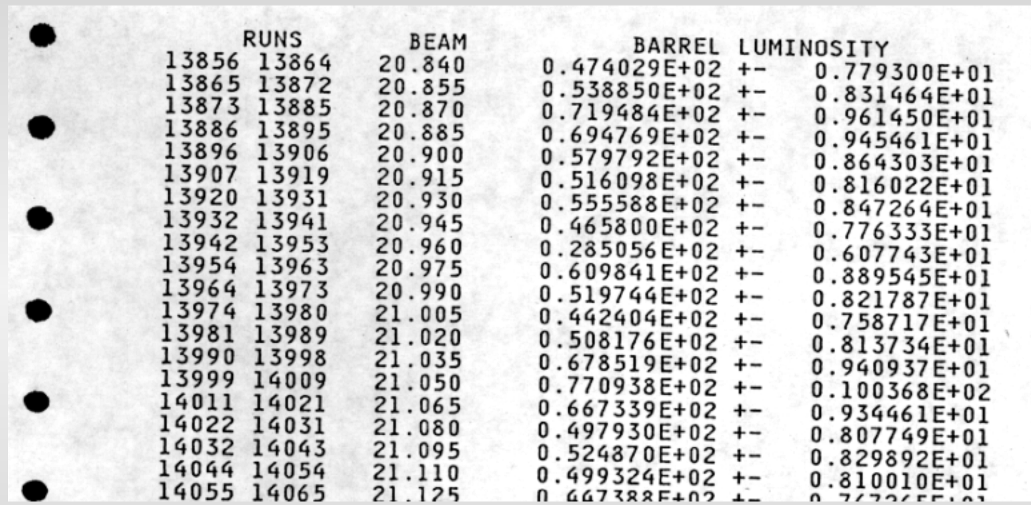
the JADE data:

- original data were located at
  - IBM mainframe at the DESY computer center
  - IBM tapes at DESY/University of Heidelberg
- DESY IBM closed completely in 1997
  - transfer of data to 'modern' data carriers (IBM /EXABYTE cartridges) and computer platforms (J. Olsson)
- 'raw' data converted into FPACK format
- multihadronic event sets are available in platform independent ZE4V-ASCII-files ('mini-DST') (E. Elsen)
  - ➢ **used for the current analysis**

The Recovery of JADE Data

- however, not all information were available in electronic format…

convert it to electronic version 'the hard way'…



RUNS		BEAM	BARREL LUMINOSITY		
13856	13864	20.840	0.474029E+02	+-	0.779300E+01
13865	13872	20.855	0.538850E+02	+-	0.831464E+01
13873	13885	20.870	0.719484E+02	+-	0.961450E+01
13886	13895	20.885	0.694769E+02	+-	0.945461E+01
13896	13906	20.900	0.579792E+02	+-	0.864303E+01
13907	13919	20.915	0.516098E+02	+-	0.816022E+01
13920	13931	20.930	0.555588E+02	+-	0.847264E+01
13932	13941	20.945	0.465800E+02	+-	0.776333E+01
13942	13953	20.960	0.285056E+02	+-	0.607743E+01
13954	13963	20.975	0.609841E+02	+-	0.889545E+01
13964	13973	20.990	0.519744E+02	+-	0.821787E+01
13974	13980	21.005	0.442404E+02	+-	0.758717E+01
13981	13989	21.020	0.508176E+02	+-	0.813734E+01
13990	13998	21.035	0.678519E+02	+-	0.940937E+01
13999	14009	21.050	0.770938E+02	+-	0.100368E+02
14011	14021	21.065	0.667339E+02	+-	0.934461E+01
14022	14031	21.080	0.497930E+02	+-	0.807749E+01
14032	14043	21.095	0.524870E+02	+-	0.829892E+01
14044	14054	21.110	0.499324E+02	+-	0.810010E+01
14055	14065	21.125	[illegible]	+-	[illegible]

JADE luminosity files

- Monte Carlo events available for $\sqrt{s}$= 35 and 44 GeV (also ZE4V – ASCII format)
- for more MC events the revival of the JADE software necessary

The Revival of the JADE Software

to generate new Monte Carlo Events requires:

a) detector simulation

b) event analysis software (reconstruction)

c) (JADE event display)

d) multihadronic filtering and packing

Source code:

- code fragments from 1974 (!)
- mixture of different FORTRAN standards/extensions
- IBM specific extensions
- IBM/370 assembler code

The Revival of the JADE Software

- historic research work using old JADE notes/PhDs/ publications necessary
- move to FORTRAN77, CERNLIB and HIGZ
- platform dependence extremely difficult

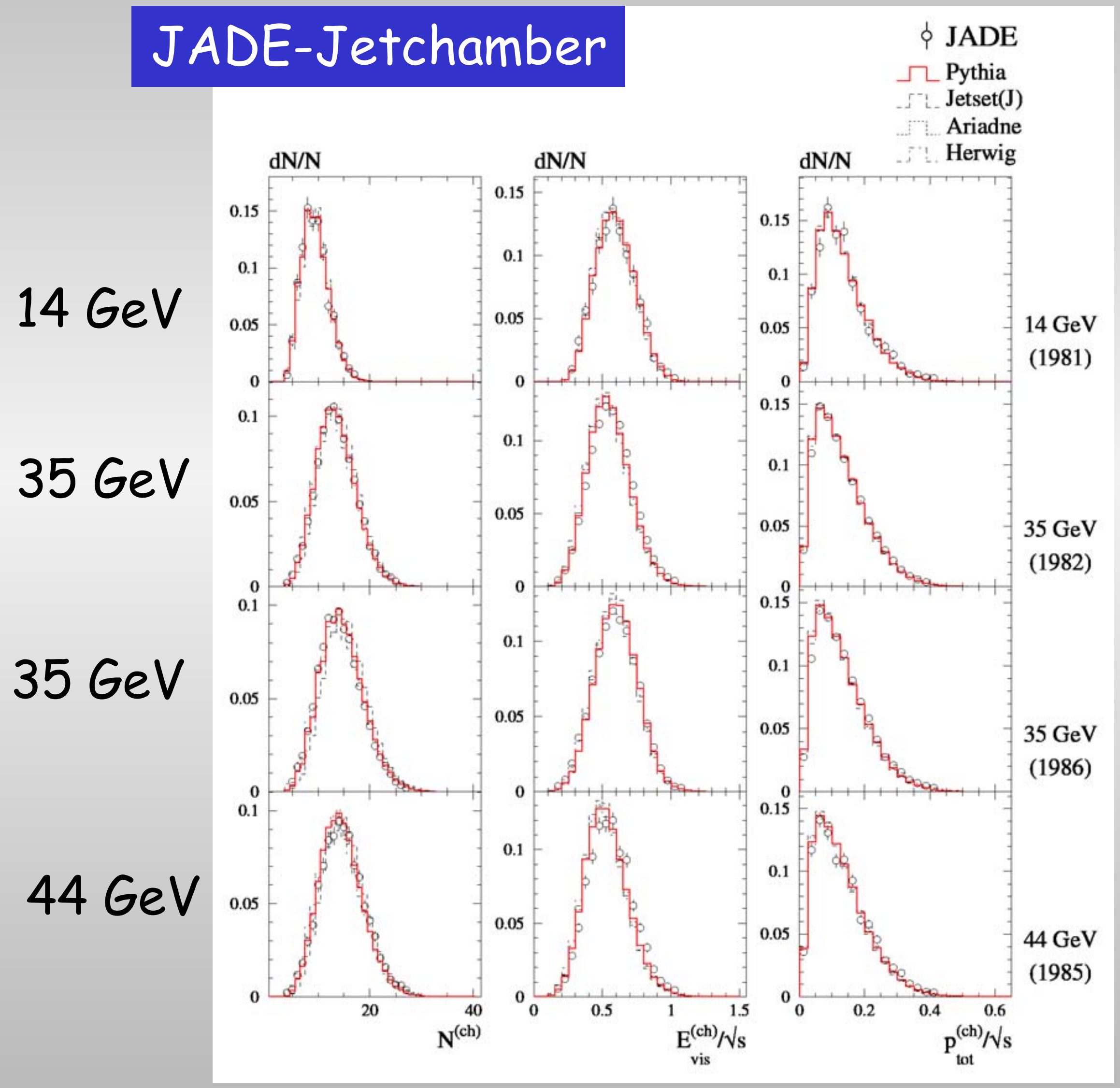
  IBM: big-endian (most significant byte stored in lowest address)

  PCs: little-endian (vice versa)

  - JADE software accesses BOS-banks not in units of of words (4 Bytes)

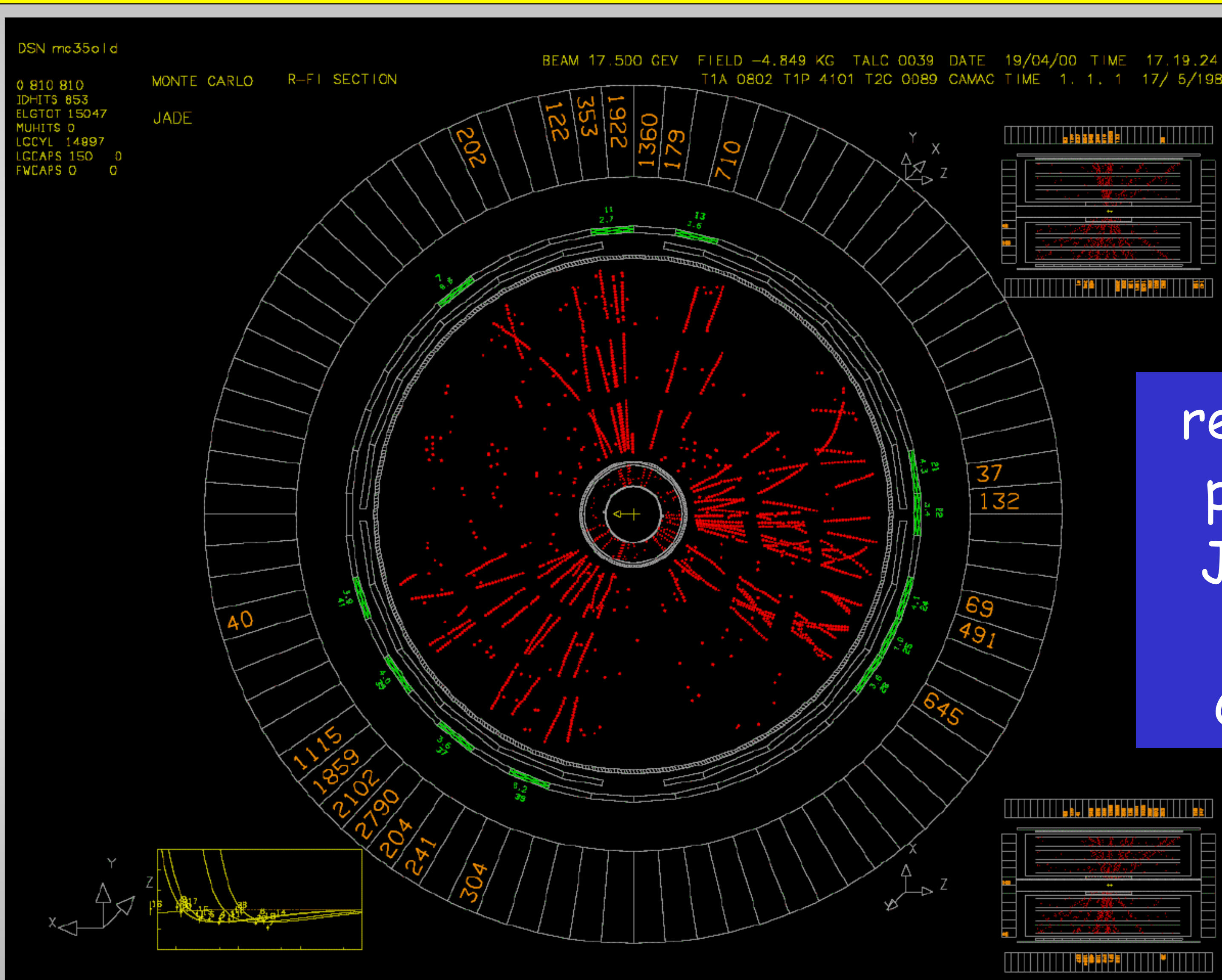
- complete installation successful on IBM RS/6000 AIX machine (with XLF compiler)

The Revival of the JADE Software



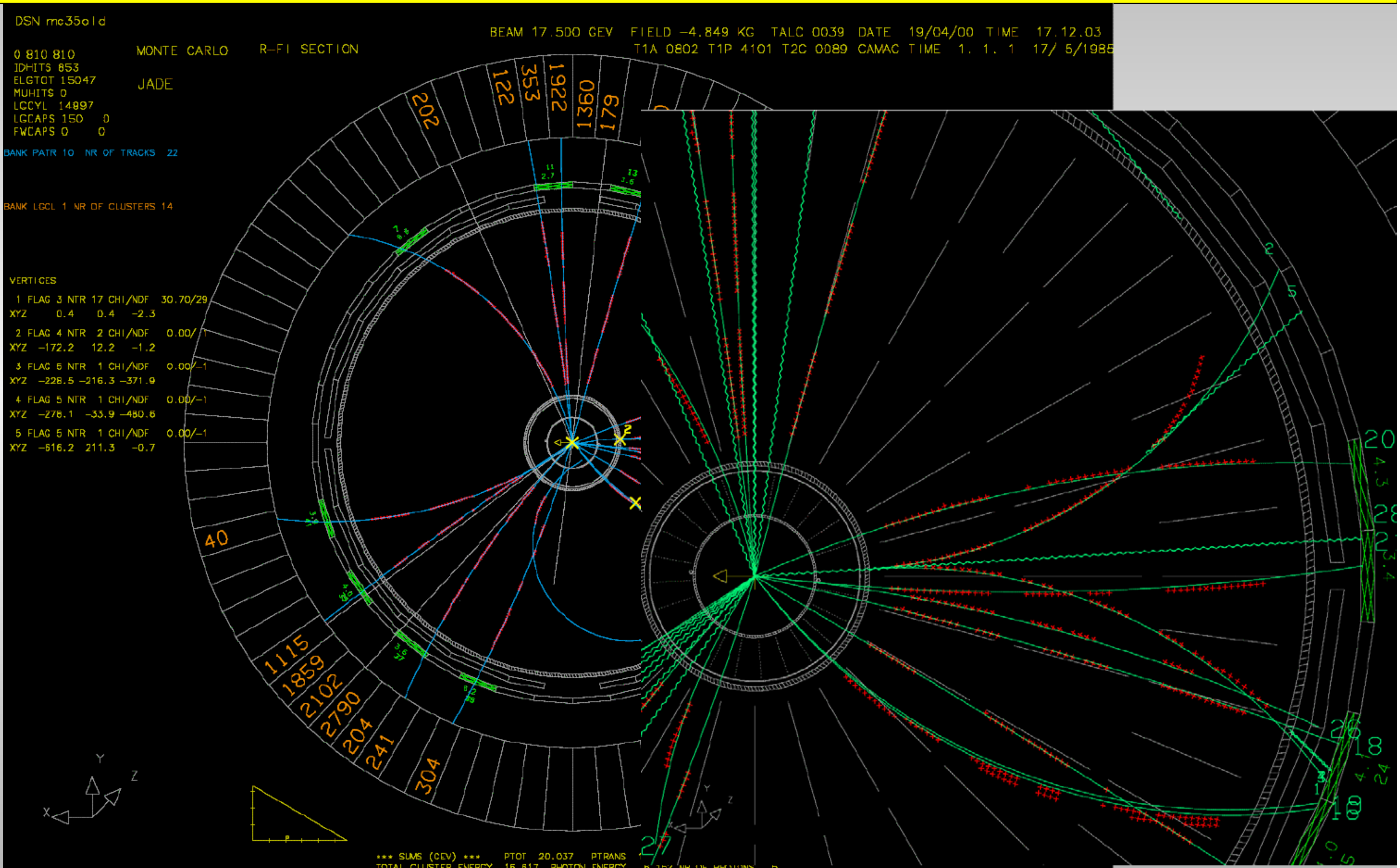
- Monte Carlo with OPAL LEP-I tune
- good description of data from 14-44 GeV

Event Display

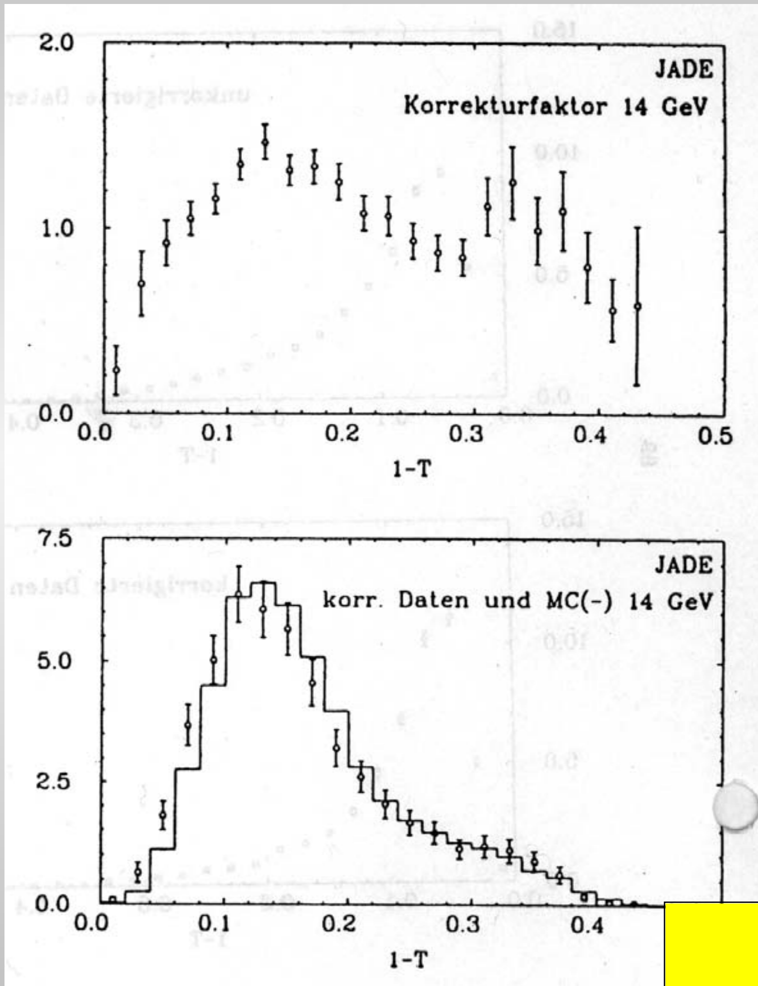


reconstructed points in the Jetchamber, TOF and Calorimeter

Event Display

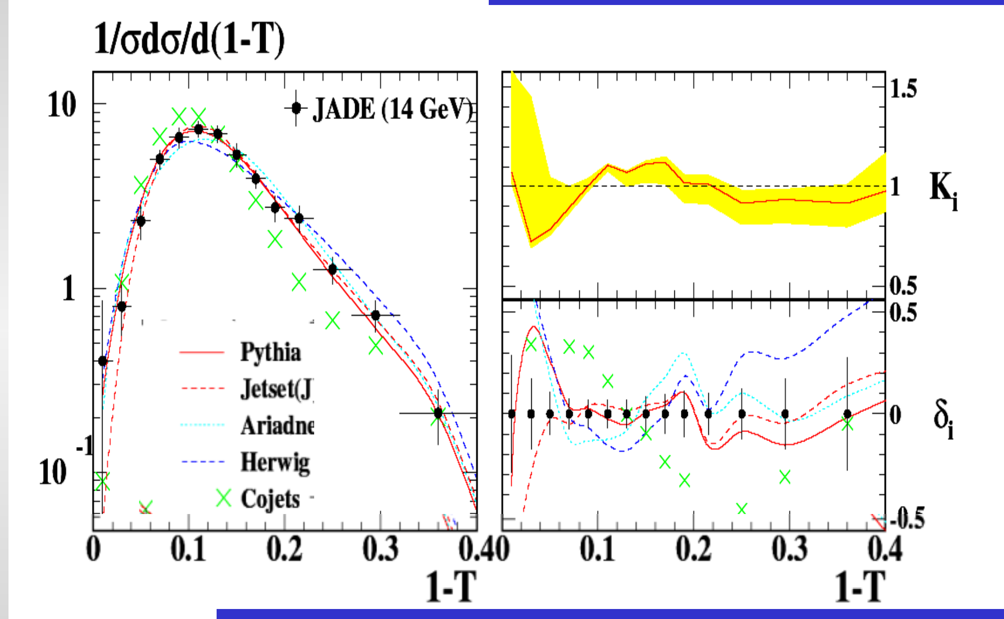


Data versus Monte Carlo



(PhD thesis Andreas Dieckmann, 1987)

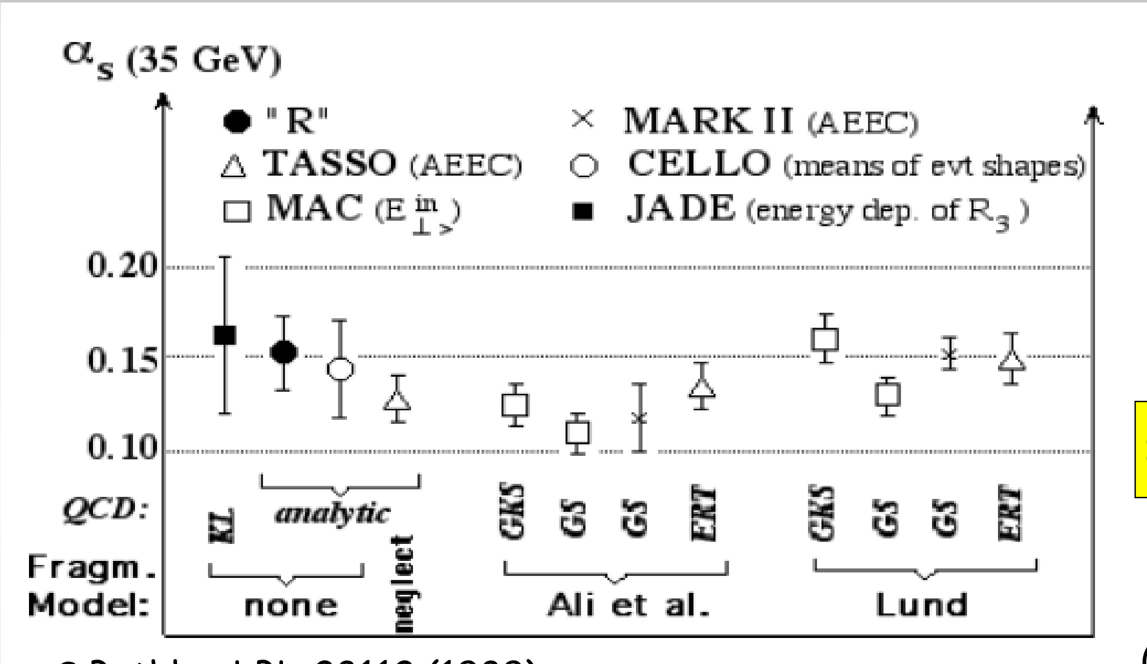
detector correction



normalised deviation from data

significant improvement of data description by Monte Carlo (LEP tune)

Status of the QCD before LEP



S.Bethke, LBL-28112 (1989)

summary value 1989:

$$\alpha_s(35\text{GeV}) = 0.14 \pm 0.02$$

$$\Rightarrow \alpha_s(M_Z) = 0.119 \pm 0.016$$

(1973: concept of asymptotic freedom
1979: discovery of gluons)

- very large dependence on Monte Carlo model
- dependence on matrix element calculation
- no renormalisation scale variation

What's happened since PETRA

LEP learned a lot from the QCD experience at PETRA, now PETRA profits from LEP

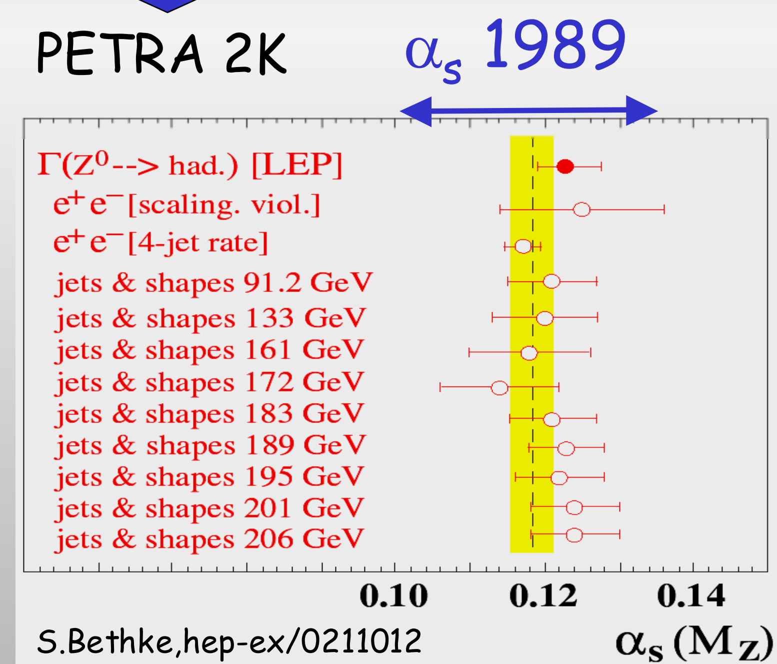
PETRA 80's

↓ important QCD input for LEP

LEP

↓ feedback for PETRA

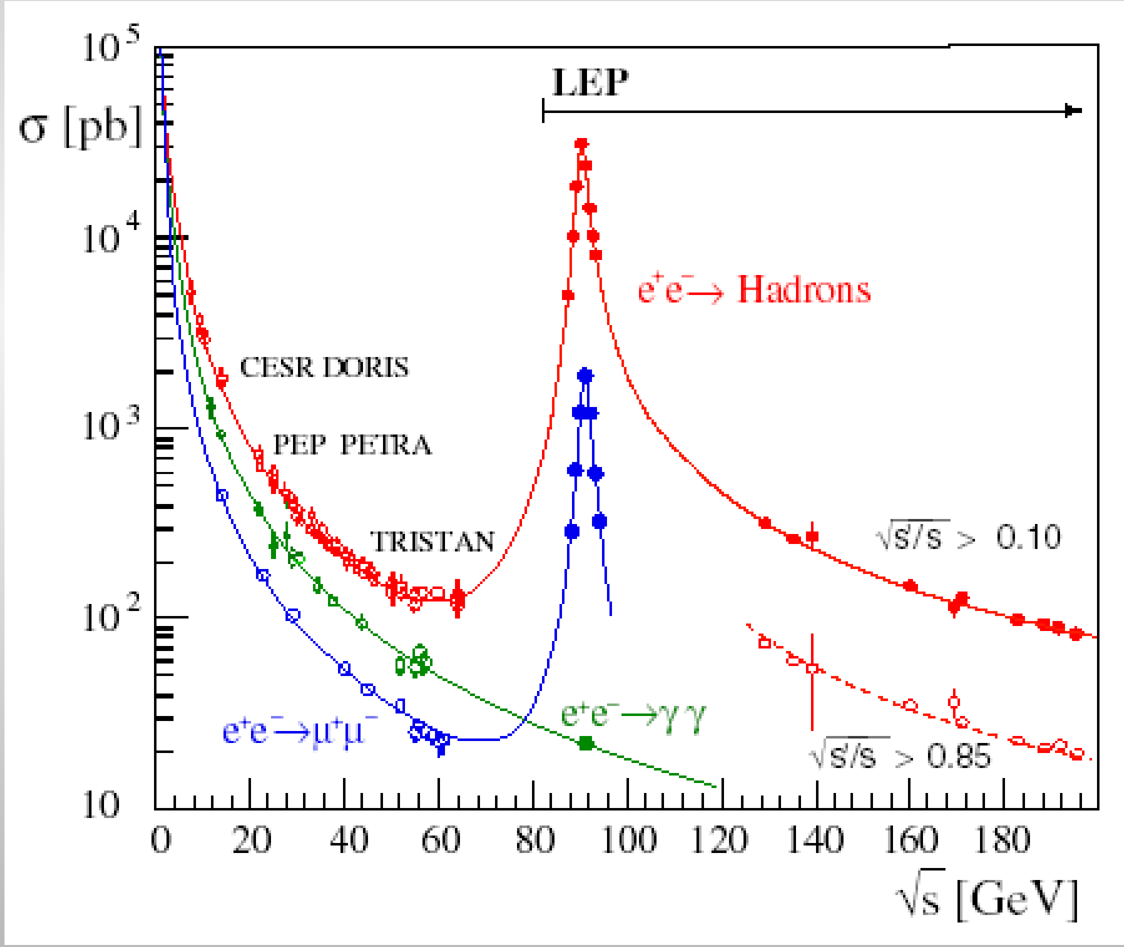
PETRA 2K



- improved theoretical predictions
  - (resummed calculations for event shapes,…)
- development of new event-shape variables
- new jet finders (Durham, Cambridge)
- improved Monte-Carlo models
- power corrections

Hadronic Final States

cross section for $e^+e^- \rightarrow$ hadrons



- σ^{had}(PETRA)

= 0.1…10nb

≈ 1/100 $\sigma^{had}(M_Z)$

Event Shapes

Event Shapes

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

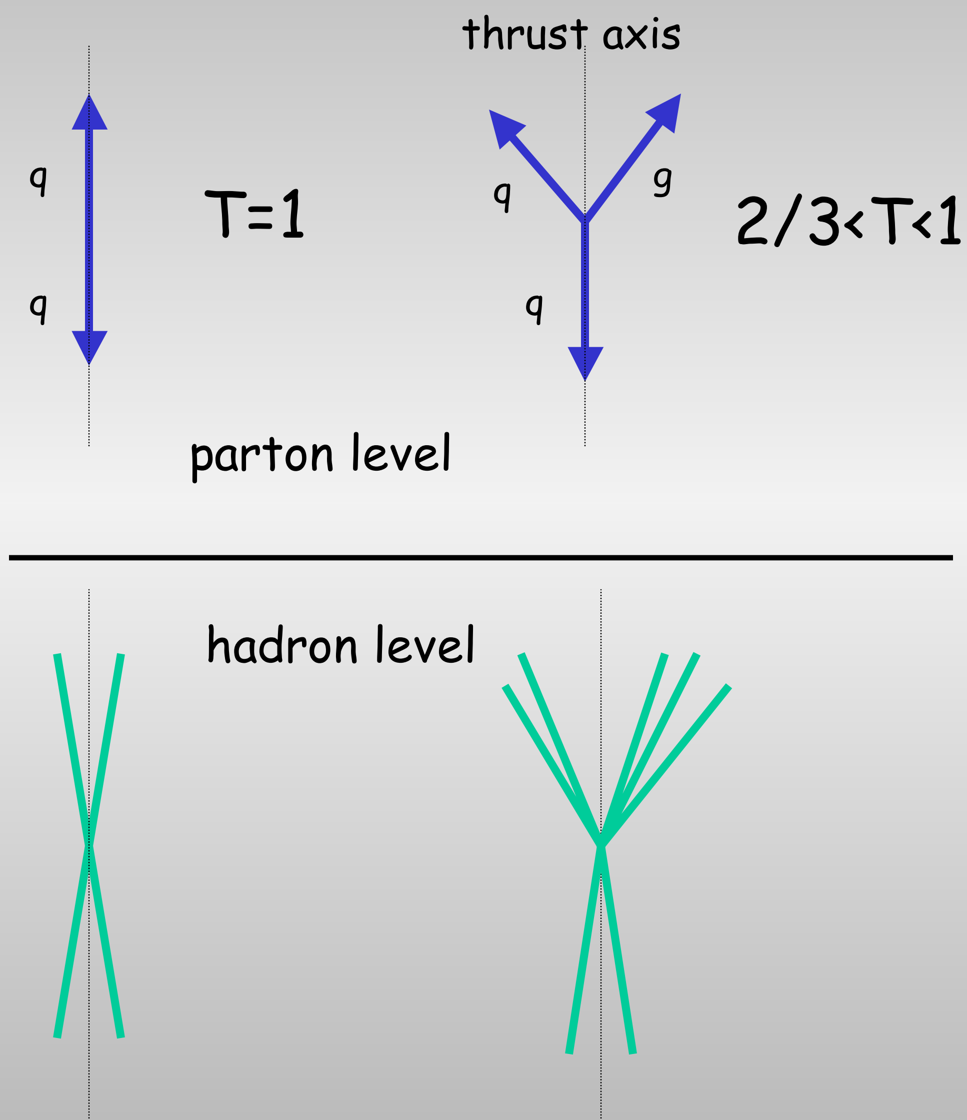
- infrared and collinear safe quantities
- resummable in all orders $\alpha_s \ln(1/F)$

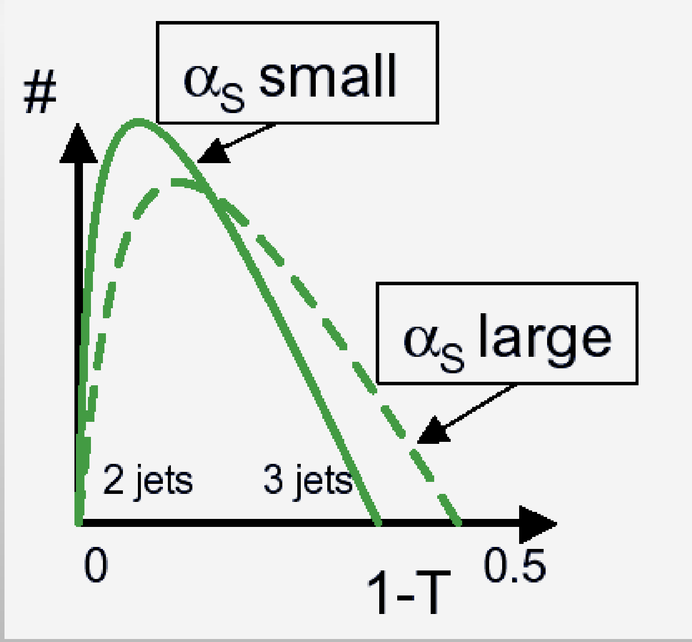
$F = 1-T, C, M_H^2, \ldots$

*) Event Shape variables only used after shutdown of PETRA

Event Shape: Thrust

$$T = \max_{\vec{n}} \left(\frac{\sum_i |\vec{p}_i \vec{n}|}{\sum_i |\vec{p}_i|} \right)$$





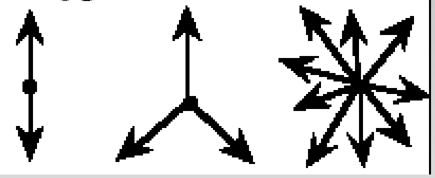
Event Shapes

- **Heavy Jet Mass** $(M_H)^2$

  event divided in two hemispheres using thrust axis

  M_H= max (inv. mass of hemisphere)$_{I=1,2}$

Typical Value for:



0 ≤1/3 ≤1/2

- **Jet Broadening** (B_T, B_W)

  momentum of hadrons in one Hemisphere perpendicular to thrust axis

  maximum (B_W) and total (B_T)

B_T: 0 ≤1/(2√3) ≤1/(2√2)
B_W: 0 ≤1/(2√3) ≤1/(2√3)

- ***C* Parameter**

  average angle between hadron pairs weighted with momentum

  (eigenvalues of linearised momentum tensor) 0 ≤3/4 ≤1

- **Differential 2-jet rate** y_{23} **(Durham scheme)**

  y_{cut} value, when an event switches from 2-Jet type to 3-Jet type

Jetfinder: JADE → Durham!

QCD Predictions

• $O(\alpha_s^2)$ calculations, (3 jet region):

(used for PETRA QCD analysis in the 80's)

$$\frac{dR}{dF} = \frac{1}{\sigma_0}\frac{d\sigma}{dF} = \frac{dA(F)}{dF}\frac{\alpha_s(\mu)}{2\pi} + \frac{dB(F)}{dF}\left(\frac{\alpha_s(\mu)}{2\pi}\right)^2 + O\left(\left(\frac{\alpha_s(\mu)}{2\pi}\right)^3\right)$$

• **Problem:**

no good description for F →0 (divergent)

• take large logarithmic L=ln(1/F) contribution into account (NLLA)

$$R(F) = \int_0^F dF' \frac{1}{\sigma_0}\frac{d\sigma(F')}{dF'} = C(\alpha_s)e^{G(\alpha_s,L)} + D(\alpha_s, L)$$

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

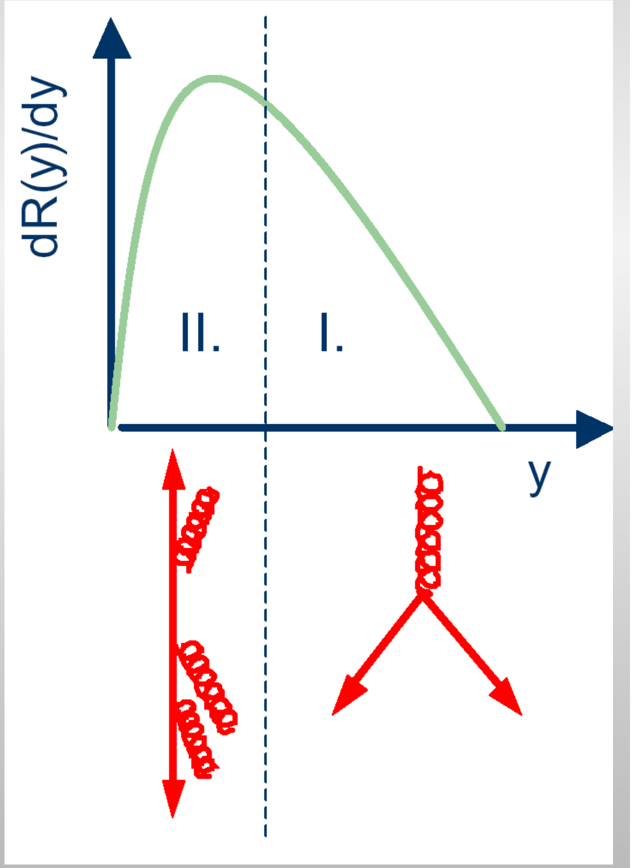
with $L = \ln(1/F)$

QCD Predictions

- match both calculations $O(\alpha_s^2)$ + NLLA:

(avoid double counting!)

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



- dependent from renormalisation scale μ
- fit perturbative predictions with scale factor $x_\mu = \mu/\sqrt{s} = 1$
- α_s as the only free parameter

Correction Procedure

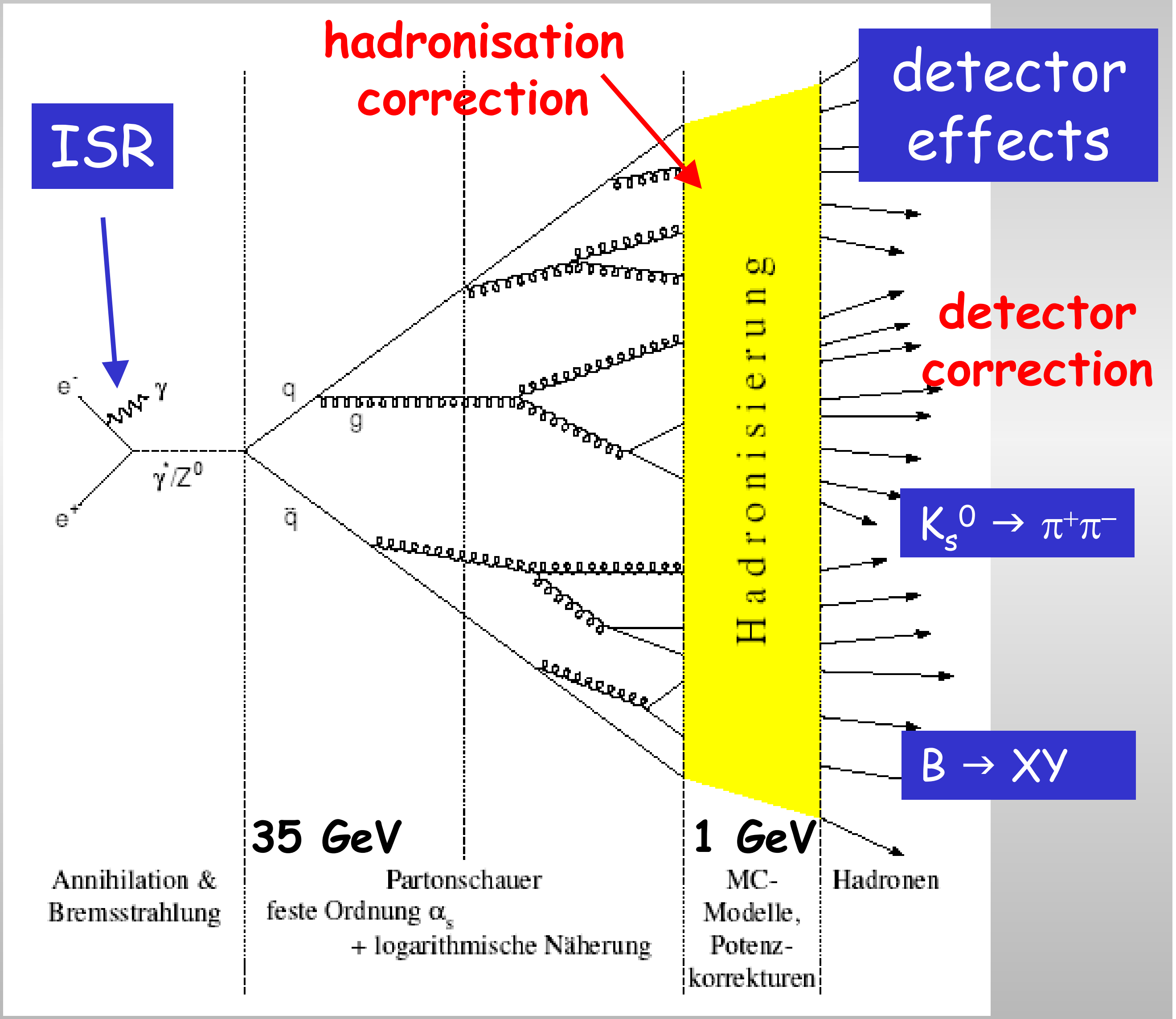
- measured distribution needs to be corrected for imperfect detector ('detector correction')
  - subtract $b\bar{b}$-background on detector level ➢see following slide
  - resolution, acceptance and secondary processes
  - photon initial state radiation (ISR)
- QCD calculations describe parton level of event shape distribution
  - correction for hadronisation effects ('hadronisation correction')

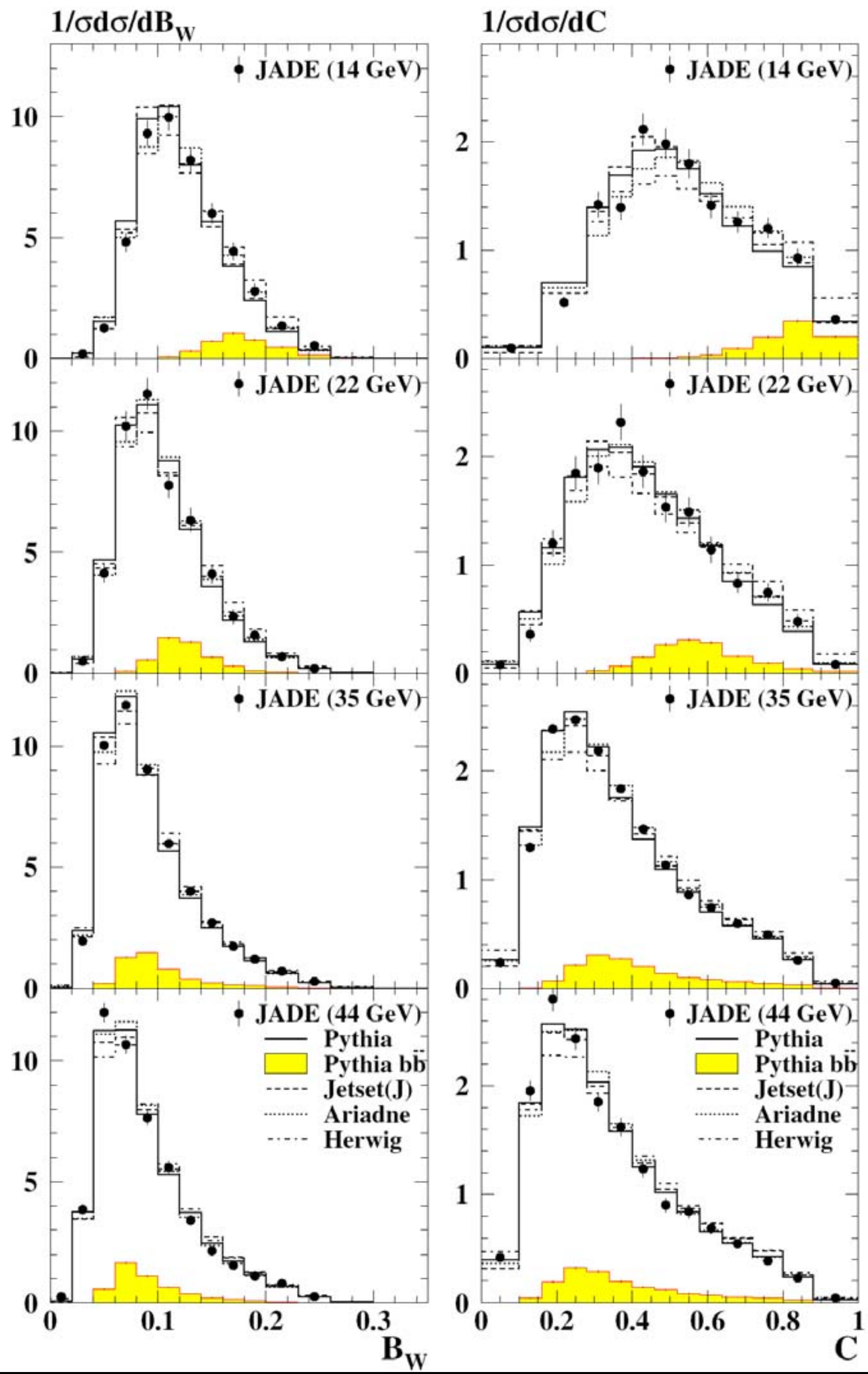
Monte Carlo Models

PT QCD:

- $O(\alpha_s^2)$+NLLA
- parton shower

- **NP QCD:**
- models (string, cluster,…)
- analytic power corrections





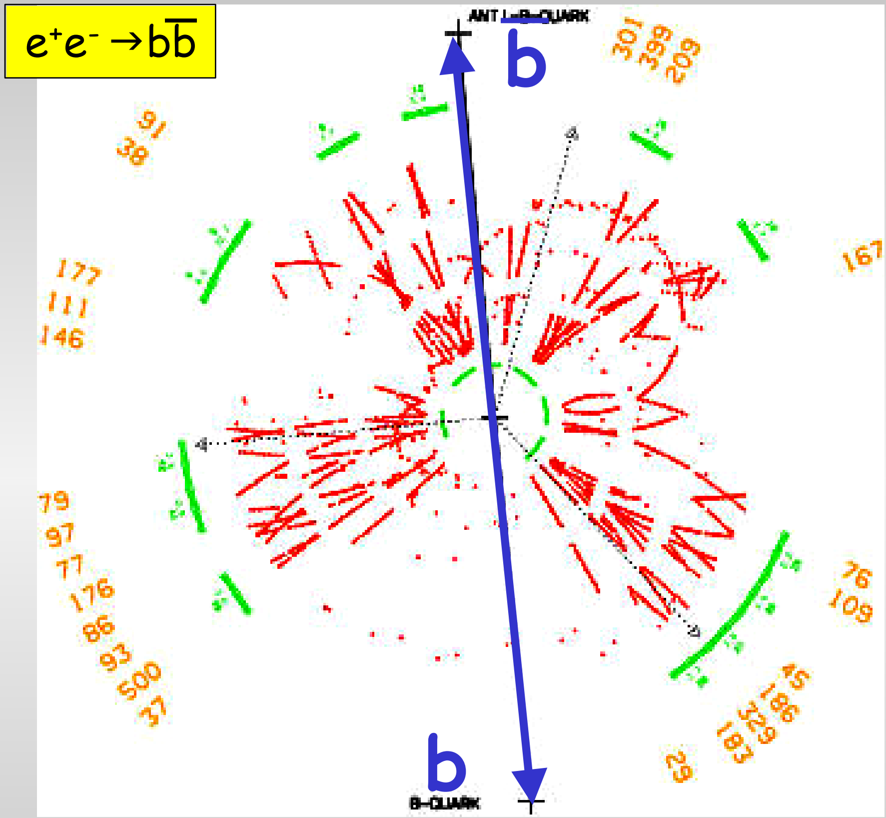
Detector Level Distributions

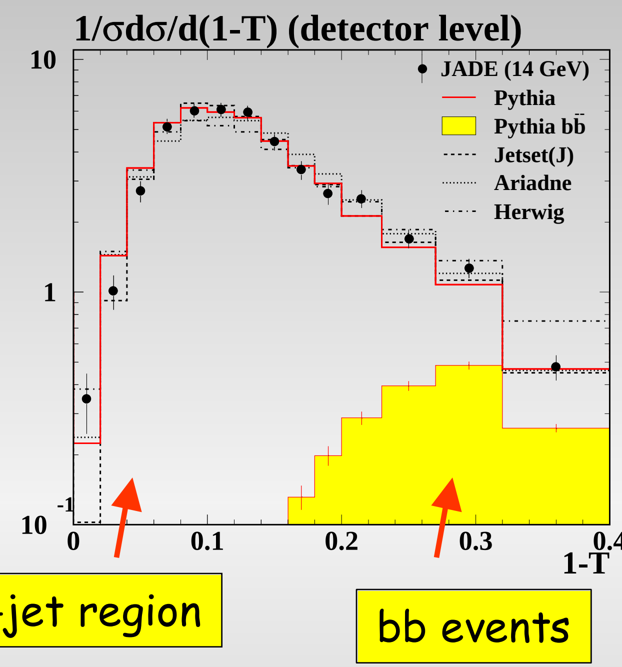
Monte Carlo + JADE simulation reproduces multihadronic events

Monte Carlo models:

- PYTHIA/JETSET
  - LLA parton shower + string
- ARIADNE
  - color dipole + string
- HERWIG
  - MLLA parton shower + cluster
- COJETS
  - LLA parton shower + independent

Correction for $b\bar{b}$-Events



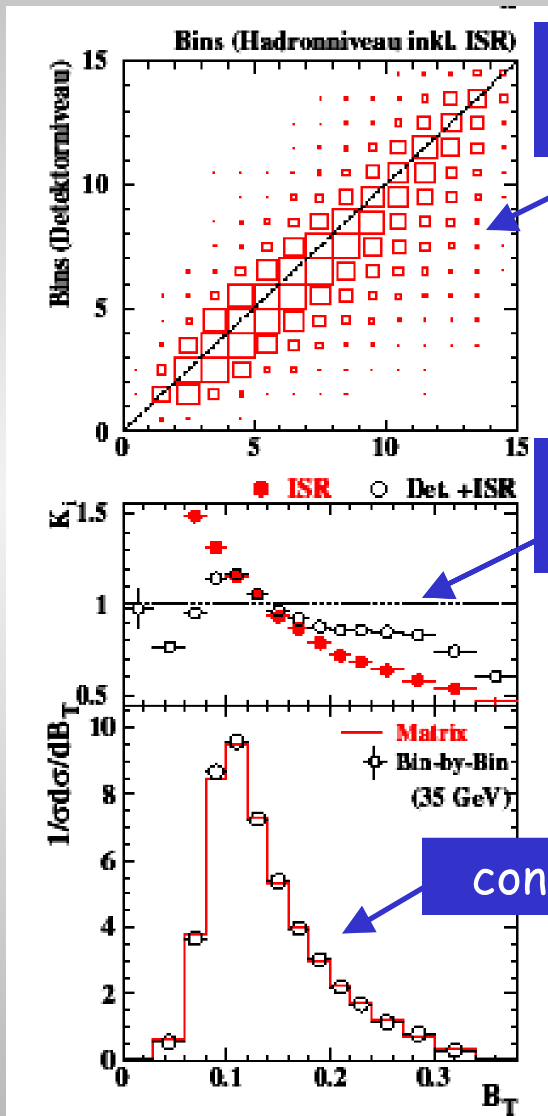


~about 9% $b\bar{b}$-events

•$b\bar{b}$ events fakes events with gluon radiation (electro weak decay)

➢subtraction at detector level

Correction Method

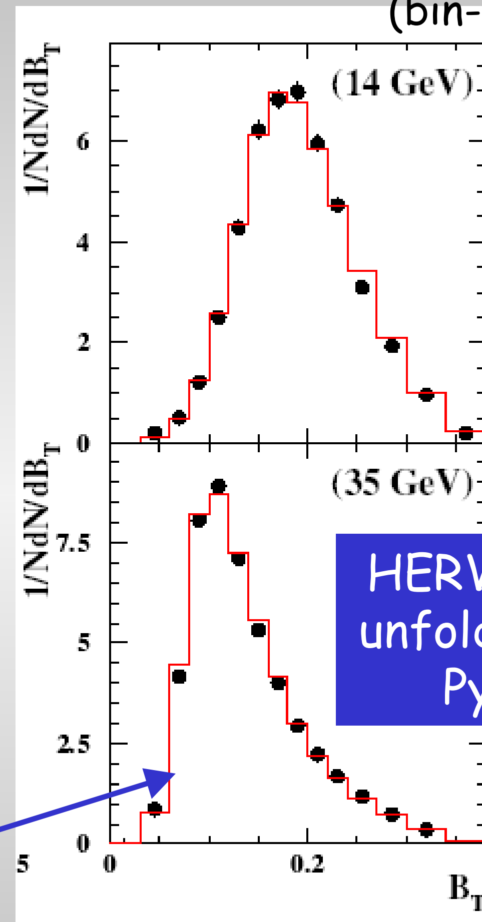


bin-by-bin corrections for 'resolution' effects

detector effects partially compensated by ISR

consistent hadron levels

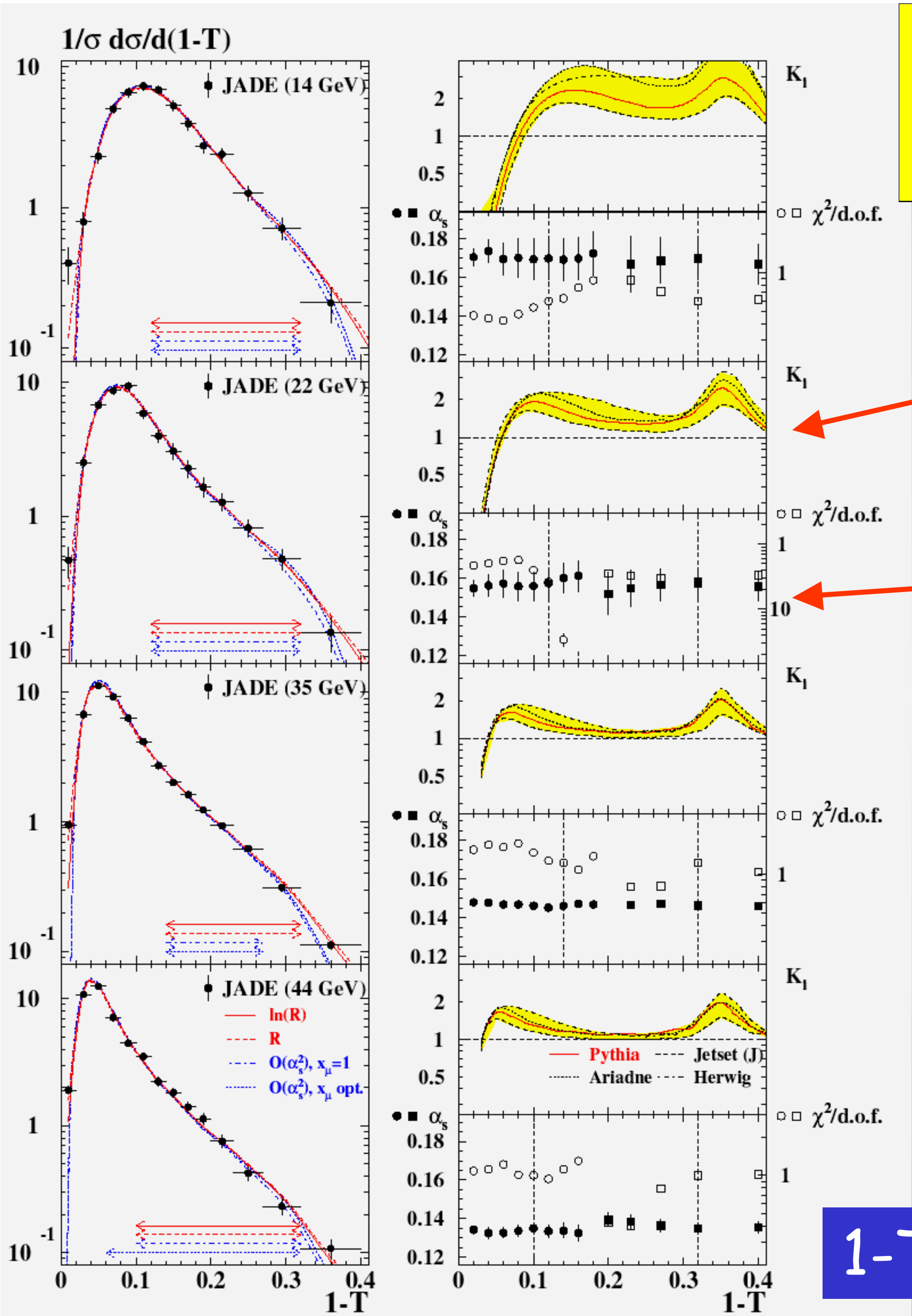
(bin-by-bin)



HERWIG MC unfolded with Pythia

'detector correction' done bin-by-bin

Fit to Distribution



correction from parton → hadron

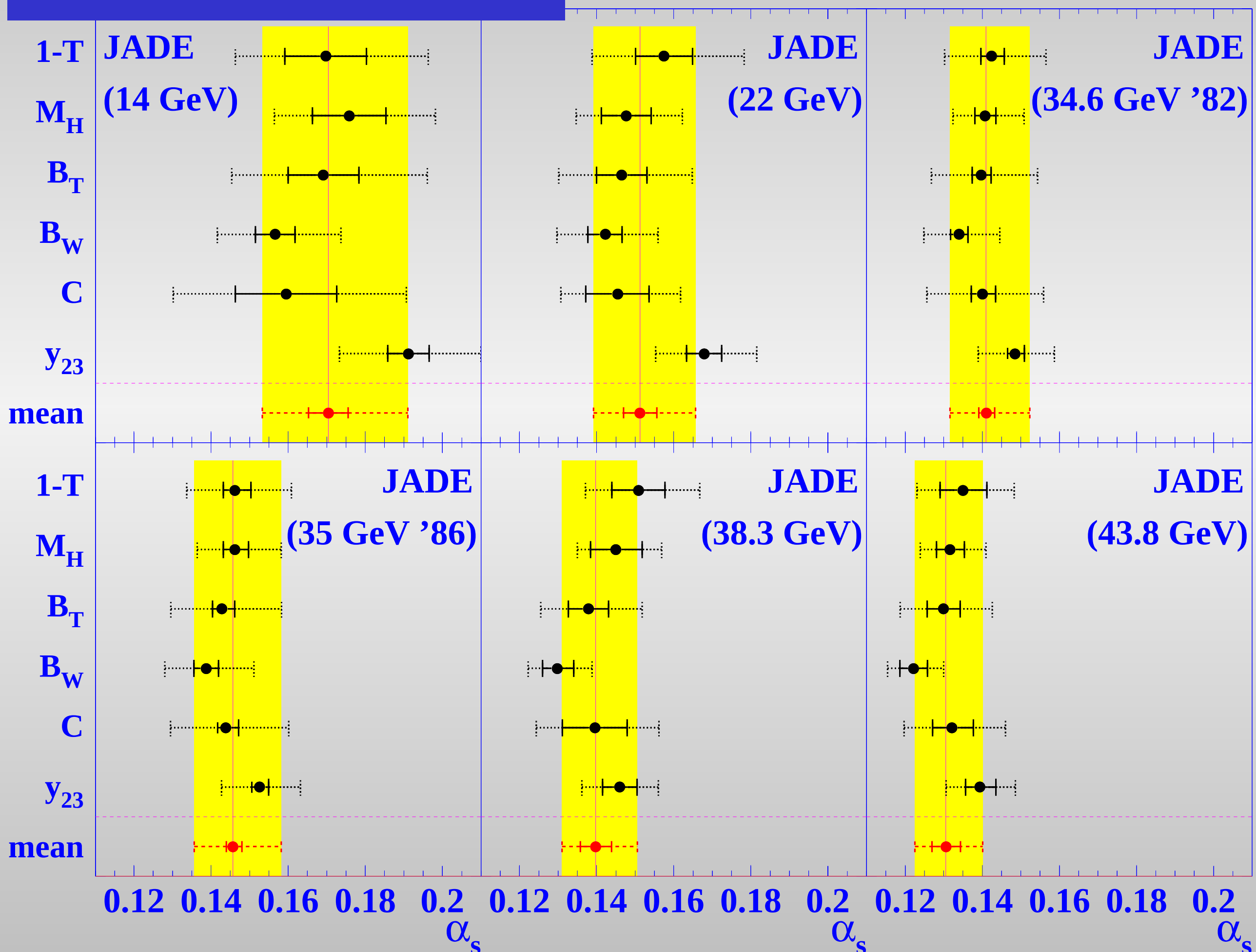
α_s and χ^2 dependence of fit range

- decreasing hadronisation correction for increasing √s
- χ^2 /d.o.f. between .2 and 2

1-T

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

α_s Results

$\sqrt{s}$ (GeV)	$\alpha_s(\sqrt{s})$	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

$\alpha_s(M_Z)^{34.8}=0.122\pm0.002\pm0.008$

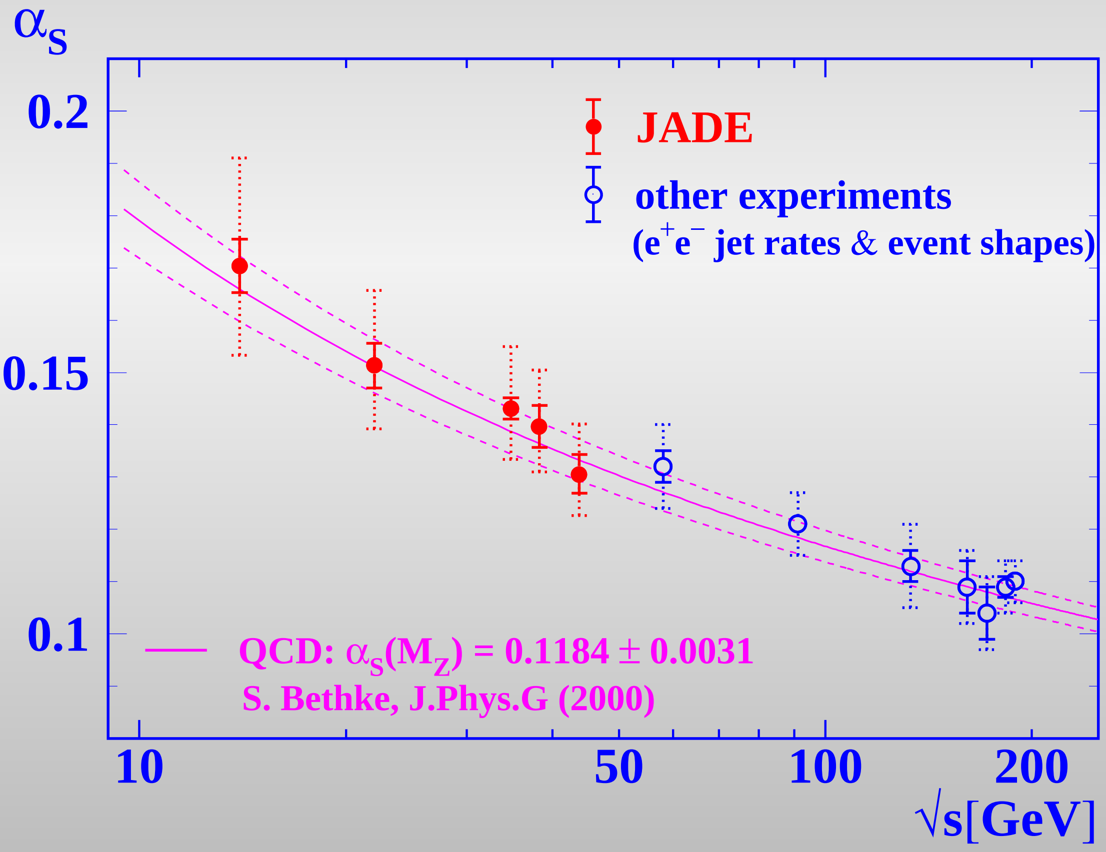
$\alpha_s(M_Z)^{Lep1}=0.121\pm0.001\pm 0.006$

S.Bethke, hep-ex/0211012

- identical with exp. error
- similar significance

Combined α_s Result

$$\alpha_s(Q) = \frac{1}{\beta_0 L} - \frac{\beta_1 \ln L}{\beta_0^3 L^2} + \frac{1}{\beta_0^3 L^3}\left[\frac{\beta_1^2}{\beta_0}(\ln^2 L - \ln L - 1) + \frac{\beta_2}{\beta_0}\right]$$



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

Fit to 14-44 GeV:

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

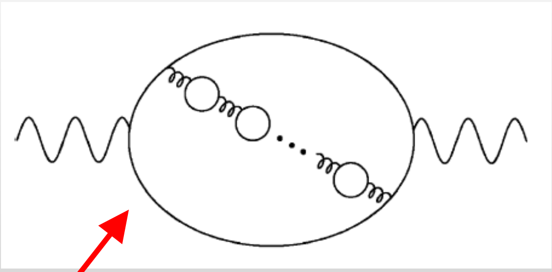
$\chi^2=3.1/4$

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

Power Corrections

remember: QCD calculations predict only distribution on parton level

- large uncertainties due to hadronisation modeling with Monte Carlo with quite a few free parameters



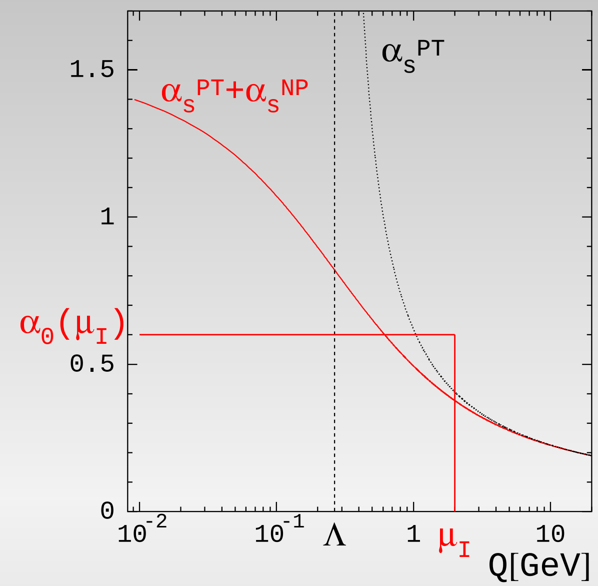
Power Corrections:

- perturbative treatment of hadronisation leads to divergences
- separate effects at large Scale (PT) and small scale (PC)

Power Corrections

μ_I : separation between PT and NP

$$\alpha_0(\mu_I) \equiv \frac{1}{\mu_I}\int_0^{\mu_I} \alpha_S(\mu)d\mu$$



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

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

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

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

universal parameter

$$P = \frac{4C_F}{\pi^2} M \frac{\mu_I}{Q}\left[\alpha_0(\mu_I) - \alpha_s(\mu_R) - \beta_0 \frac{\alpha_s^2}{2\pi}\left(\ln(\frac{\mu_R}{\mu_I}) + \frac{K}{\beta_0} + 1\right)\right]$$

Dokshitzer-Marchesini-Webber (DMW) structure of power corrections (1996)

Fit to Distributions

global fit of

•pQCD + Power Corrections (DMW model)

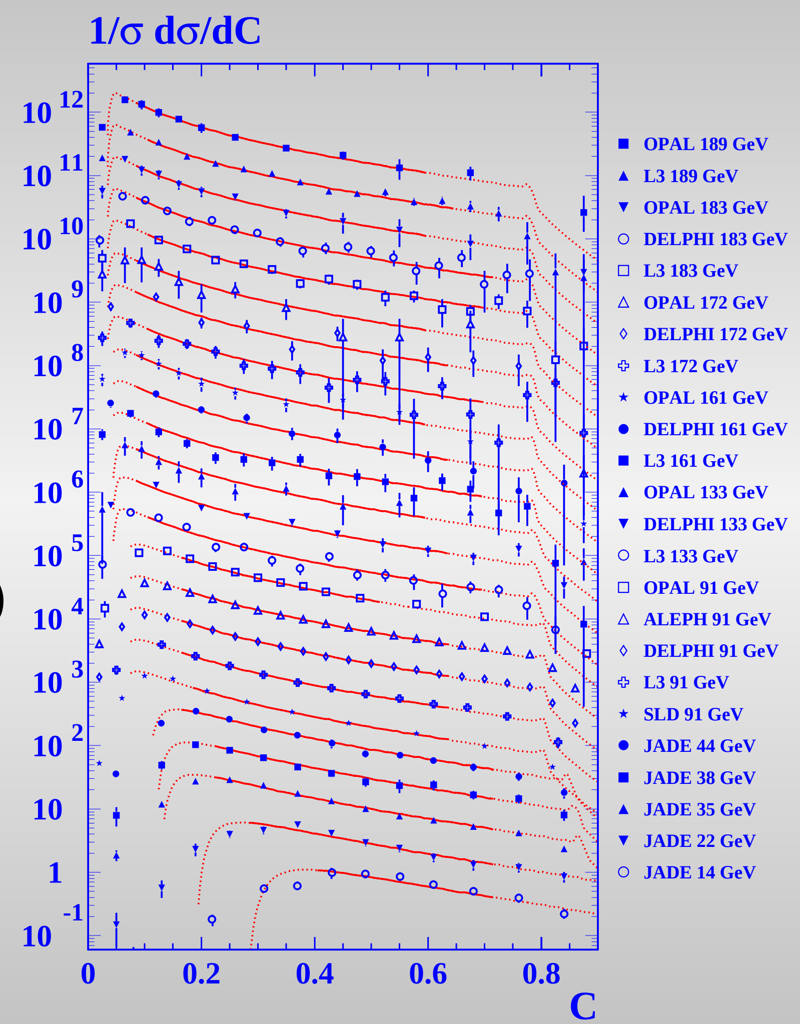
to overall event shape and mean values data from:

(PETRA,PEP,TRISTAN,SLC,LEP)

($\sqrt{s}$ = 14-189 GeV)

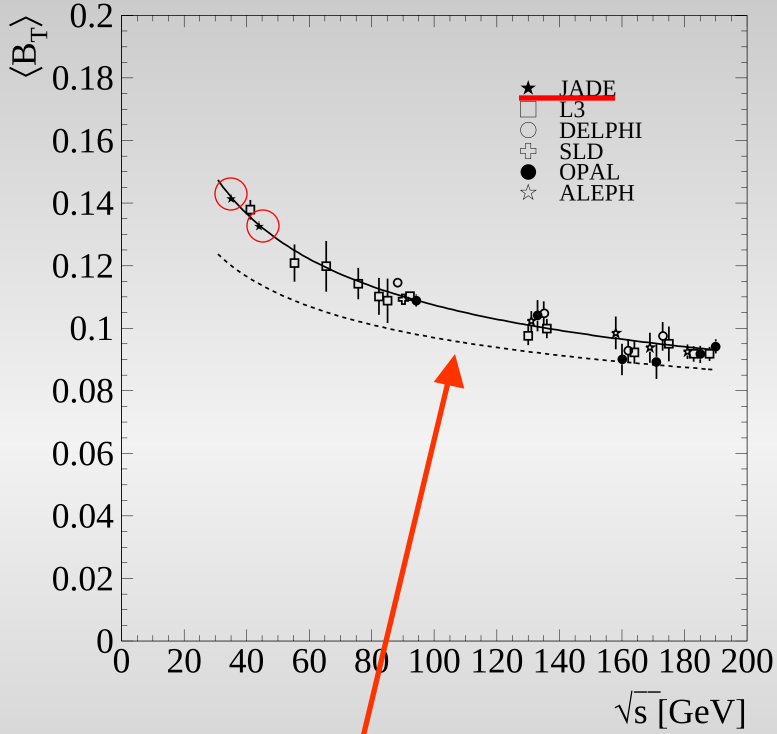
2 free fit parameters:

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



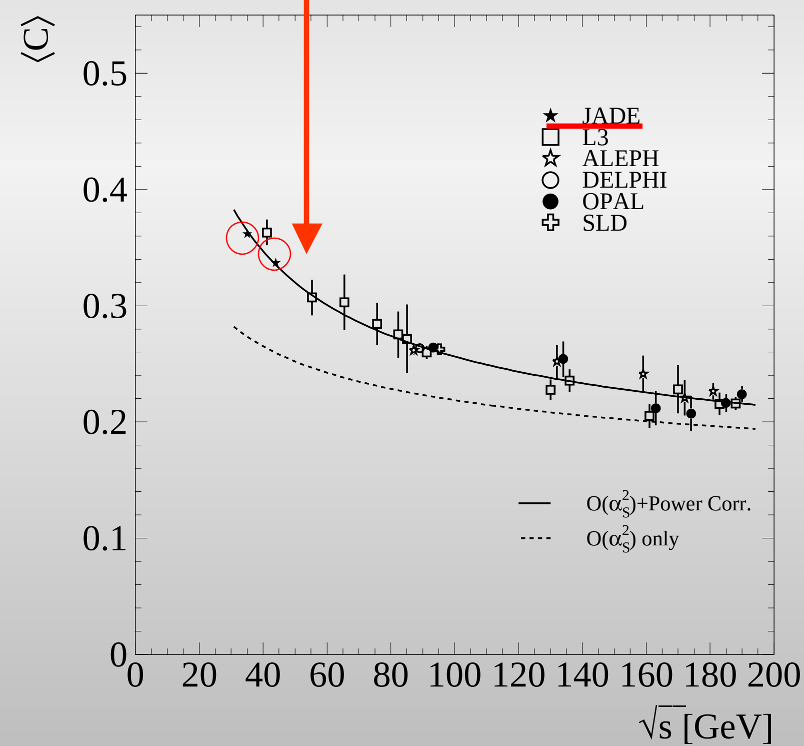
χ^2=181/216 d.o.f

α_s, α_0 Fits to Mean Values

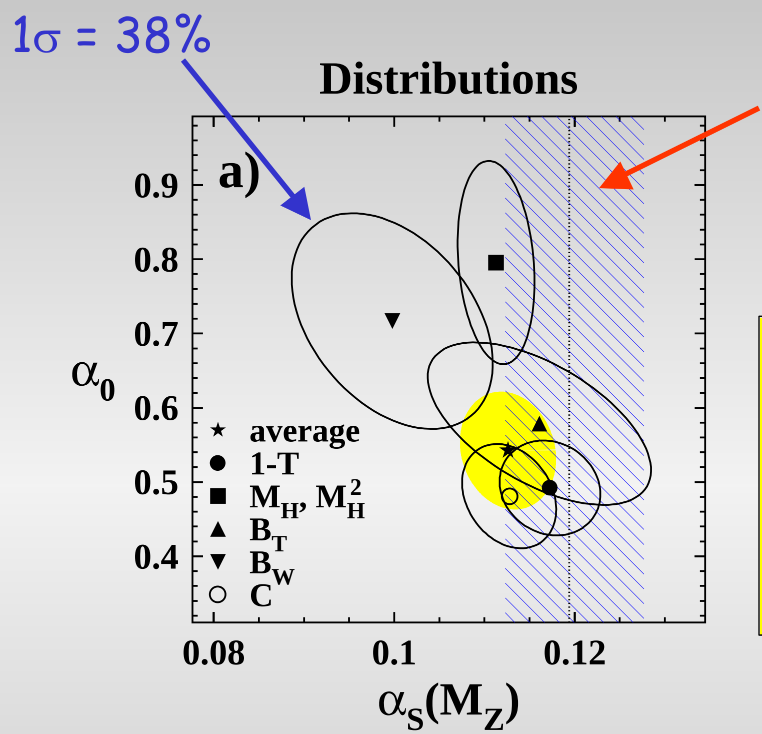


perturbative predictions

perturbative predictions plus power corrections



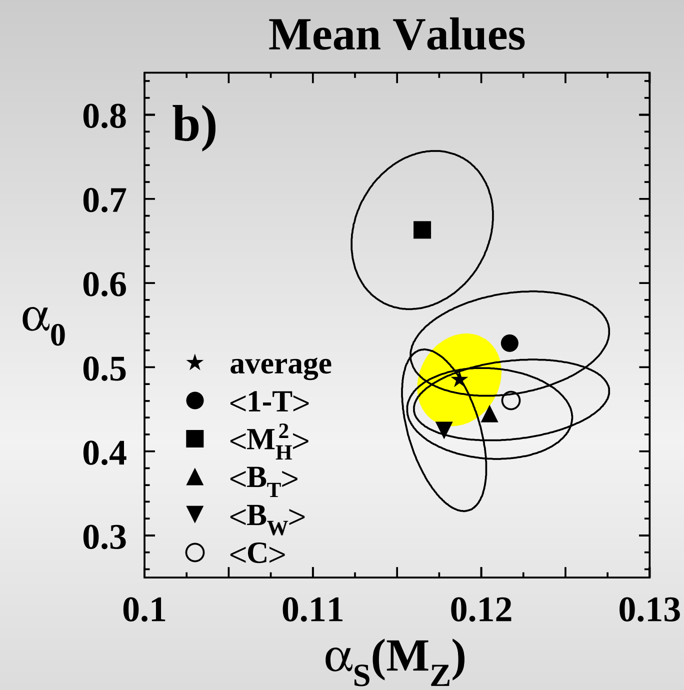
α_s, α_0 Fit Results



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

~-80%

(single fit)

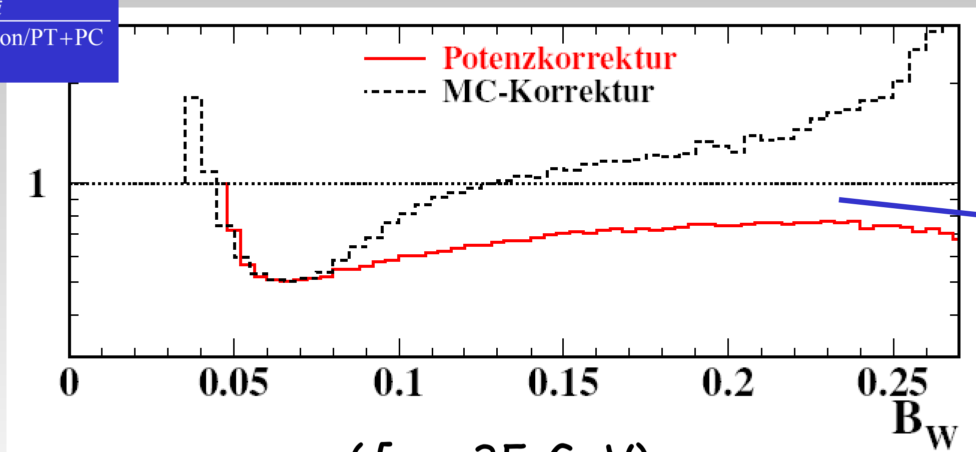


Distribution	Fit	Stat	Exp	Theo
$\alpha_s(M_{Z^\circ})$	0.1126	±0.0005	±0.0037	+0.0044 -0.0030
α_0(2 GeV)	0.542	±0.005	±0.032	+0.084 -0.060

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

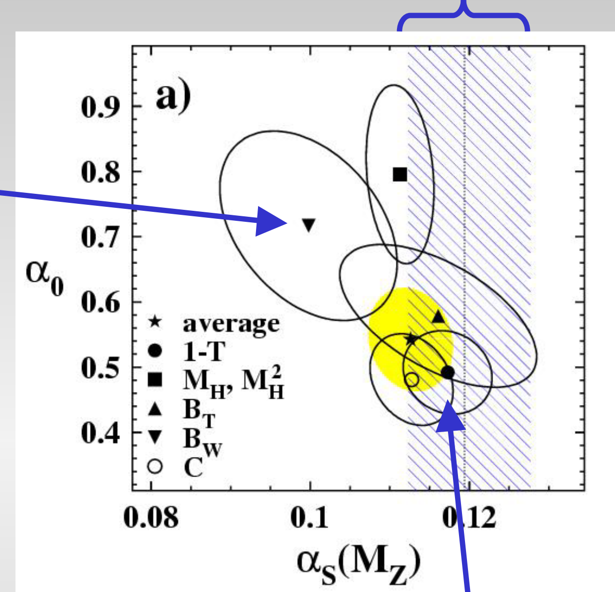
Comparison MC vs PC

$$k_i = \frac{\sigma_i^{\text{parton}}}{\sigma_i^{\text{hadron/PT+PC}}}$$



(√s = 35 GeV)

α_s from 'default' analysis

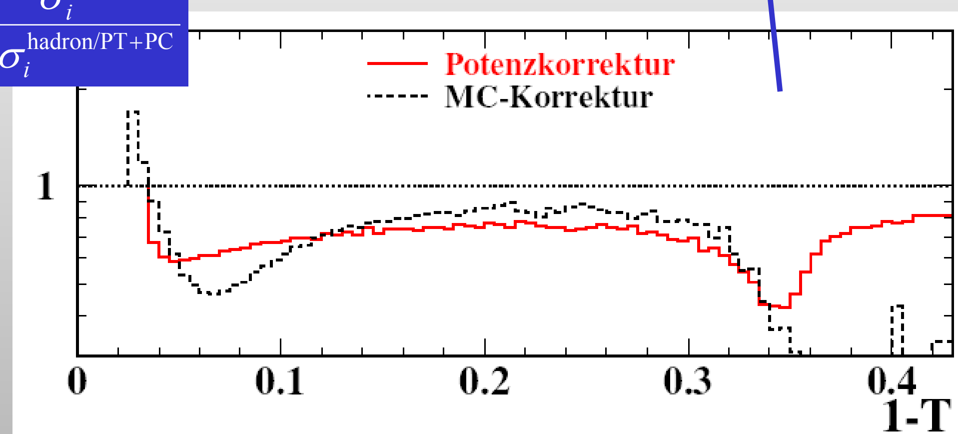


perturbative QCD calculations need to be corrected for hadronisation

a) Monte Carlo model

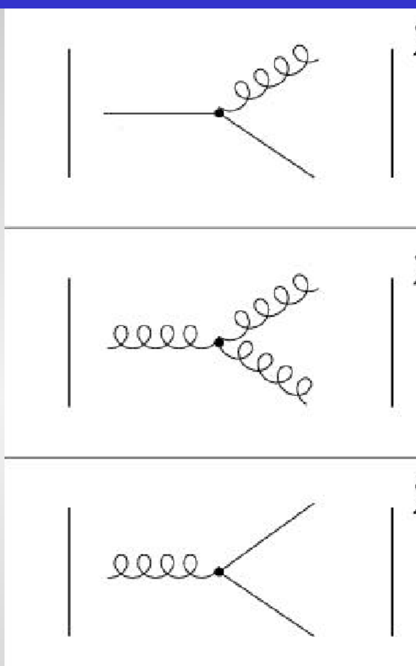
b) power corrections

$$k_i = \frac{\sigma_i^{\text{parton}}}{\sigma_i^{\text{hadron/PT+PC}}}$$



Color Structure from Event Shapes

QCD color factors:



$|\ldots|^2 \sim \alpha_s C_F$

$|\ldots|^2 \sim \alpha_s C_A$

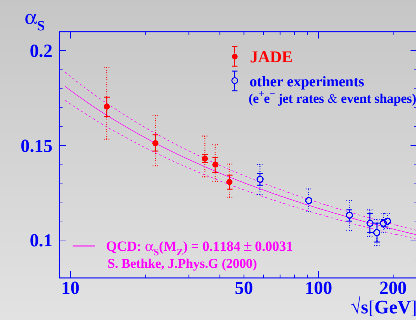
$|\ldots|^2 \sim \alpha_s T_F N_f$

color factors determined by SU(3)

running of α_s

$\beta_0=\beta_0(C_A,n_f)$

$\beta_1=\beta_1(C_A,C_F,n_f)$

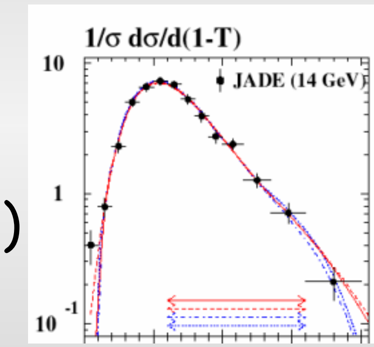


perturbative prediction

$A=A(C_F)$

$B=B(C_A,C_F,n_f)$

$NLLA=NLLA(C_A,C_F,n_f)$

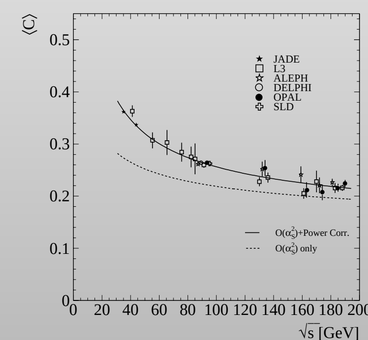


power corrections

$P=P\ (C_A,C_F,n_f)$

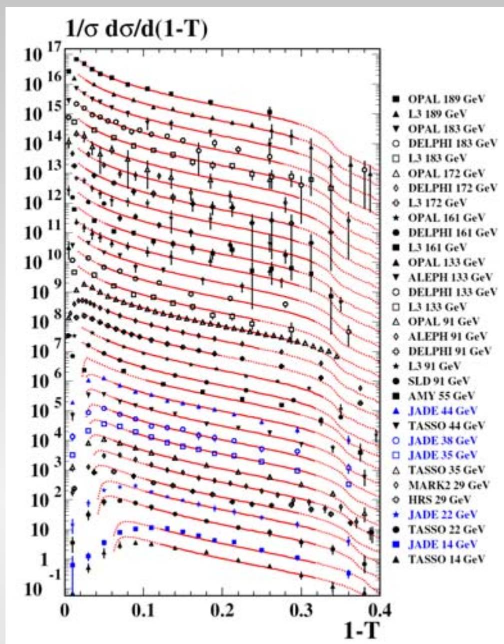
$M=M(C_A,n_f)$

$D_F=D_F\ (C_A,C_F,n_f)$



sensitivity from radiative corrections

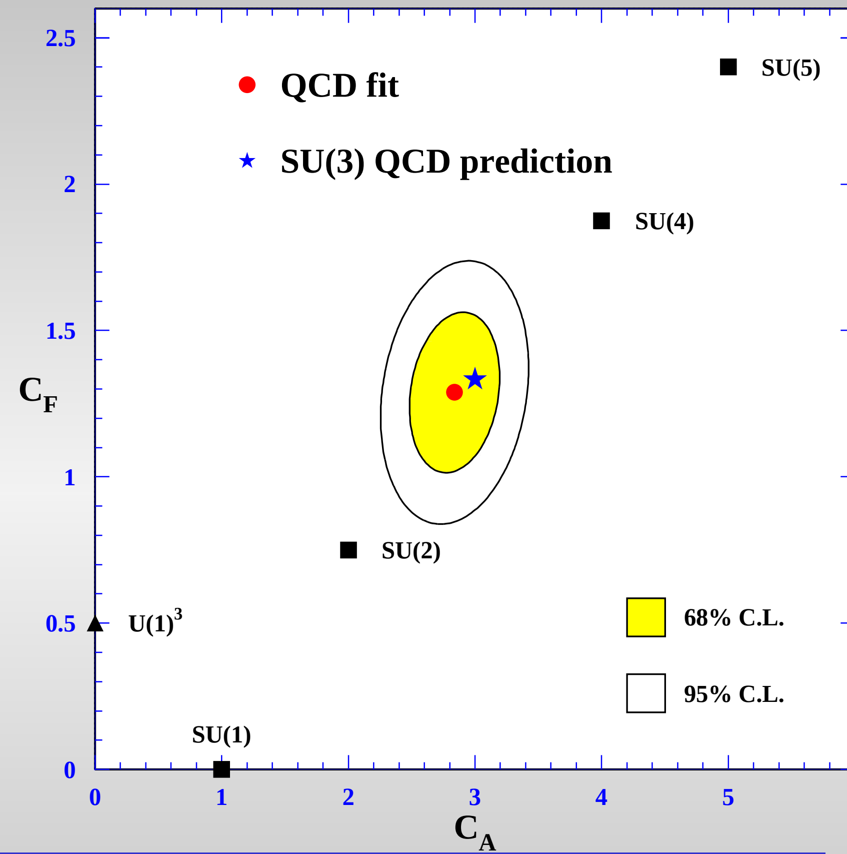
Color Structure from Event Shapes



running of α_s

pertubative prediction

power corrections



- result consistent with 4-Jet-Angular Analysis
- errors comparable or even smaller

C_A=2.84 ±0.24 (QCD:3)
C_F=1.29 ±0.18 (QCD:4/3)

$\rho_{fit}(C_A-C_F)$=0.19

Measurement of σ_L and σ_T

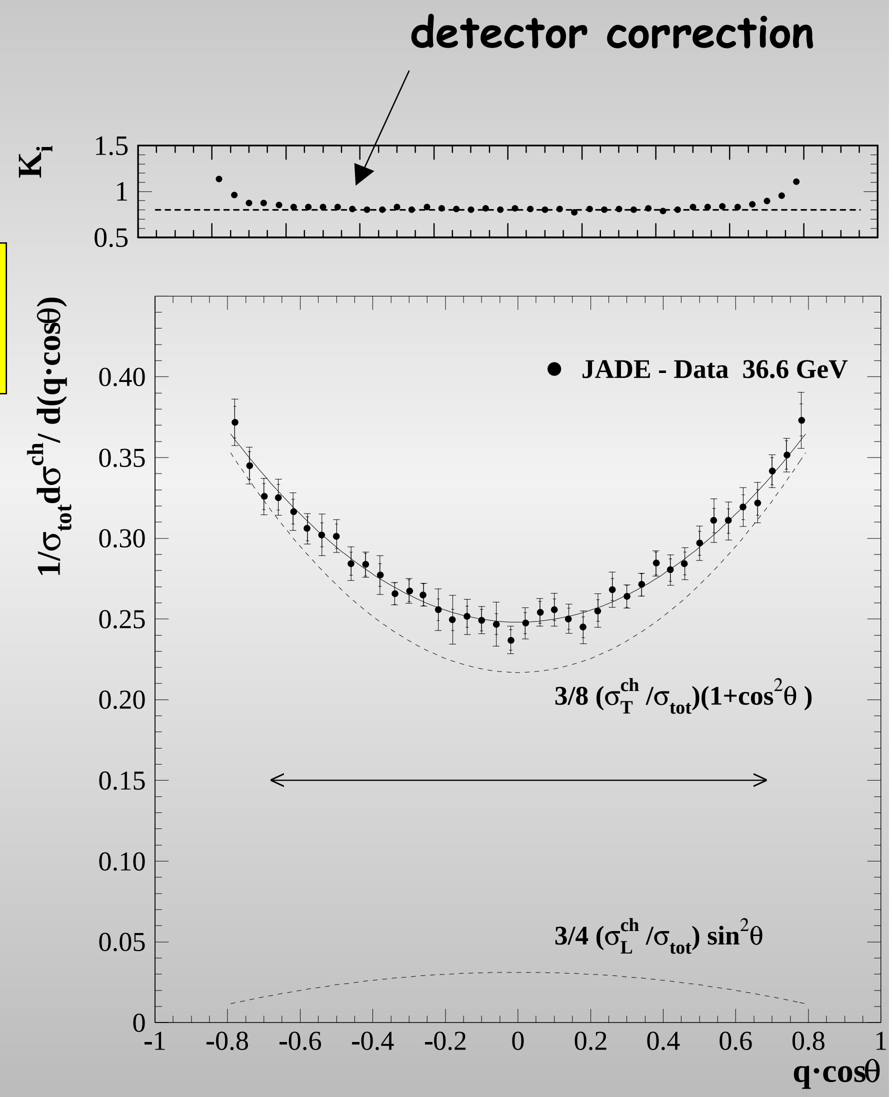
Differential cross section for hadron production:

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

(no quark-antiquark separation
→ no asymmetric term)

σ_L~0 at quark production vertex

σ_L<>0
→ contribution from gluon radiation

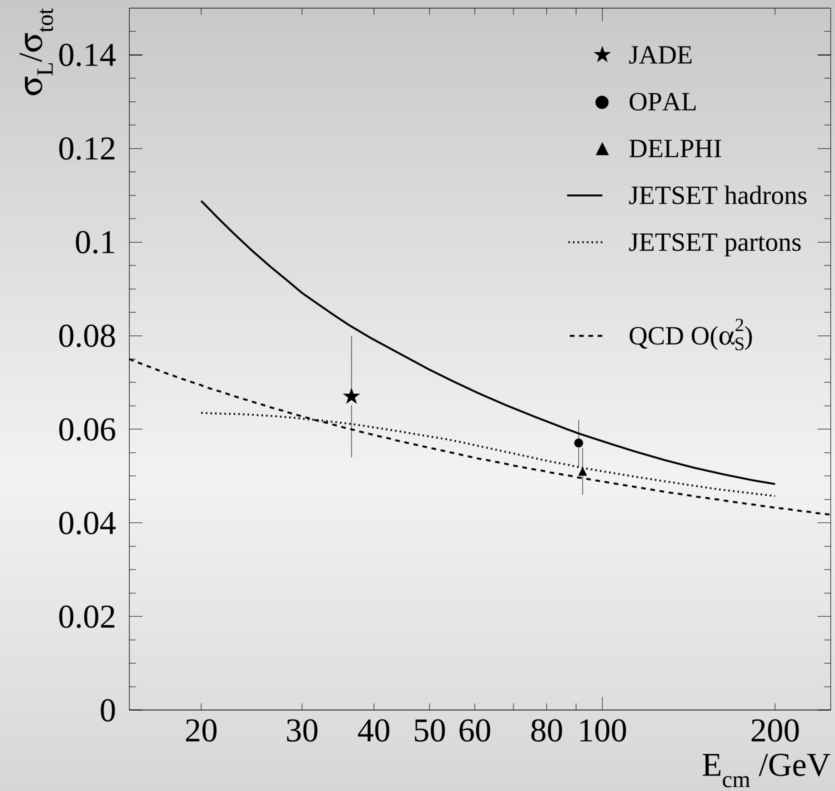


Measurement of σ_L and σ_T

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

QCD calculation:

$$\left(\frac{\sigma_L}{\sigma_{tot}}\right)_{PT} = \frac{\alpha_s}{\pi} + 8.444\left(\frac{\alpha_s}{\pi}\right)^2$$



$\alpha_s(36.6\ GeV) = 0.150 \pm 0.02$

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

(def. Analysis: $\alpha_s(M_{Z^\circ})$= 0.1194 ±0.008 (stat.))

Power Correction for σ_l/σ_{tot}:

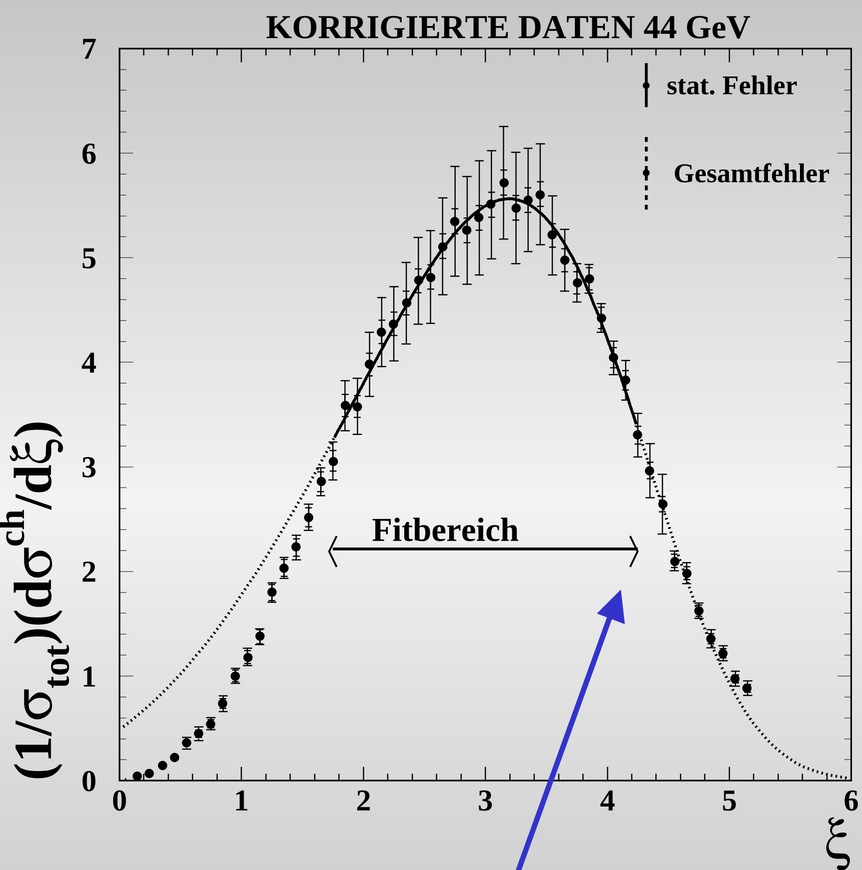
$$\delta_{PC} = \frac{8M}{3\pi}\frac{\mu_I}{Q}\left(\alpha_0(\mu_I) - \alpha_S\right)$$

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

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

Measurement of $\xi = \ln(1/x)$

$x = 2p/\sqrt{s}$



region with 'soft' hadrons
(ξ=4 ~ p=0.4 GeV/c)

Tests of soft QCD predictions

Input:

- next-to-leading-log-Approximation (NLLA)
- local parton hadron duality (LPHD)
  properties of partons at end of shower similar to hadrons

Prediction:

- shape around peak and $\sqrt{s}$ dependence
- effects of heavy quarks

Measurement of $\xi=\ln(1/x)$

Fit to distribution (skewed gaussian):

$$F_q(\xi,Y)=\frac{N(Y)}{\sigma\sqrt{2\pi}}\cdot\exp\left(\frac{k}{8}-\frac{s\delta}{2}-\frac{(2+k)\delta^2}{4}+\frac{s\delta^3}{6}+\frac{k\delta^4}{24}\right)$$

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

N(Y): normalization related to charged multiplicity

$\langle\xi\rangle$=function of Y + O(1)

$\delta=(\xi-\langle\xi\rangle)/\sigma$

σ:width

s: skewness

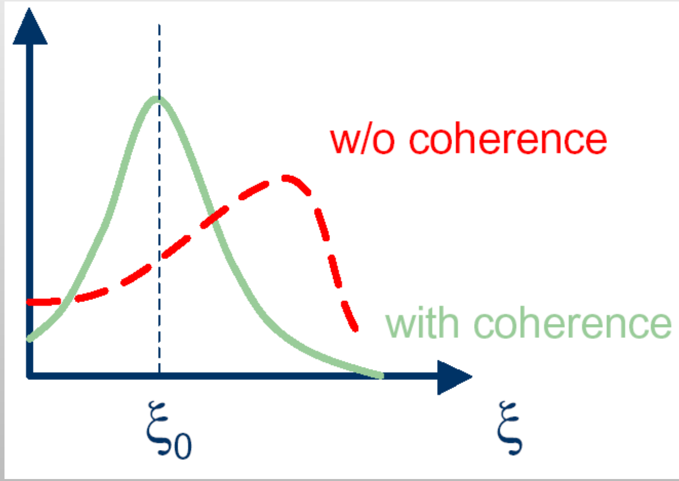
k: kurtosis

ξ^0: peak position

Y dependent!

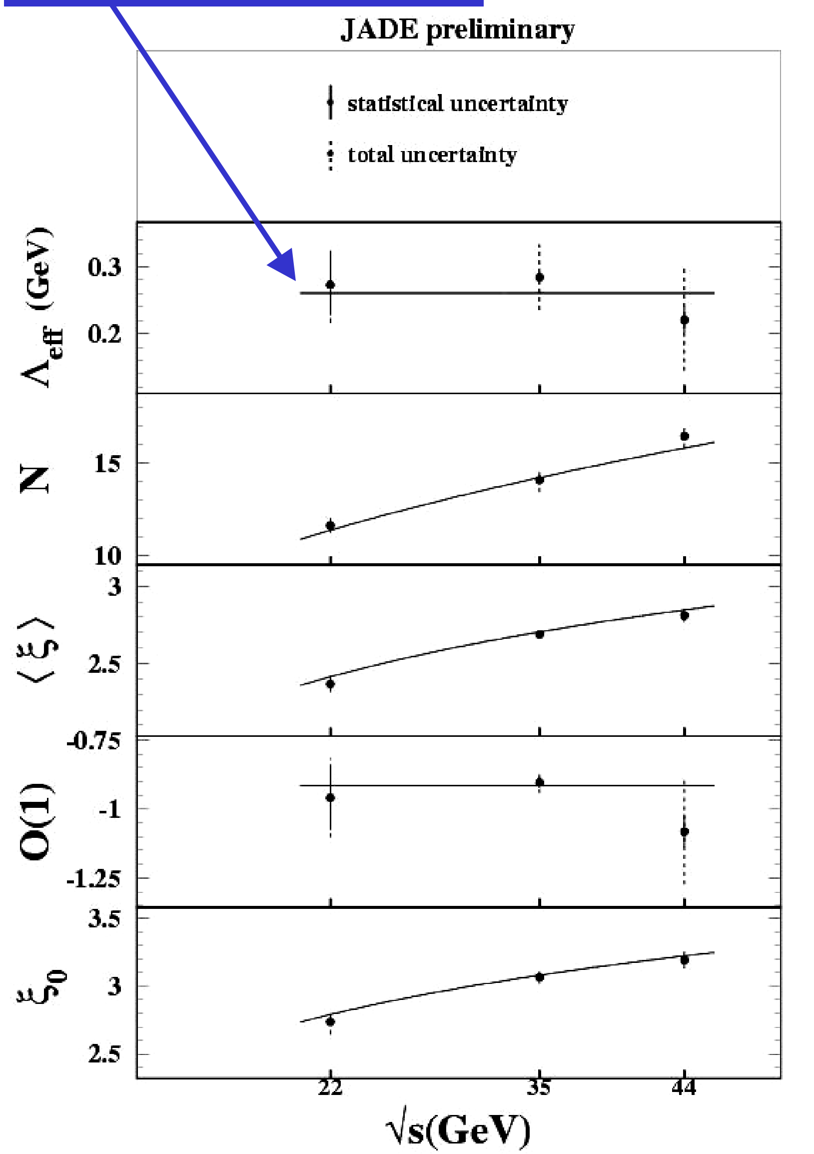
$\xi^0-\langle\xi\rangle=(11+2N_f)/(32*9C_A)$

Fong-Webber Parameterisation
(with coherence)



Measurement of ξ=ln (1/x)

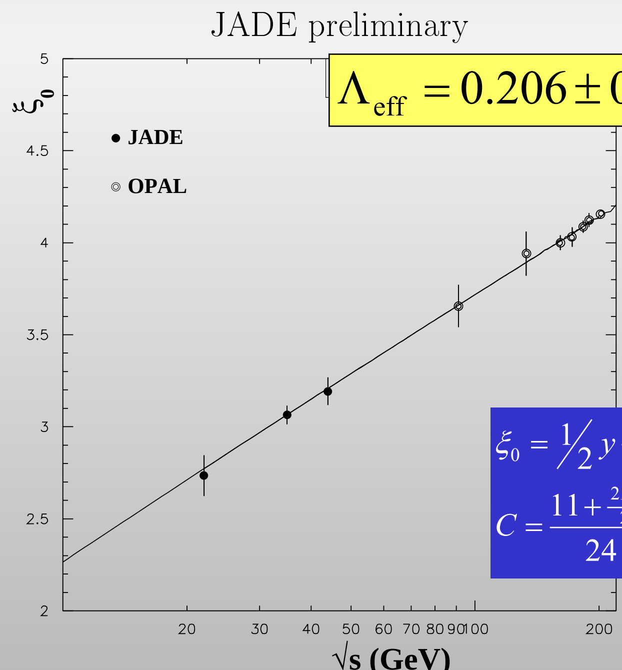
Fong-Webber prediction



fit NLLA (Fong,Webber)

Λ_{eff},N and <ξ>,ξ^0or O(1)

<ξ> ,ξ^0 and N depend on √s
Λ_{eff} and O(1) constant



$$\Lambda_{\rm eff} = 0.206 \pm 0.001 \pm 0.003$$

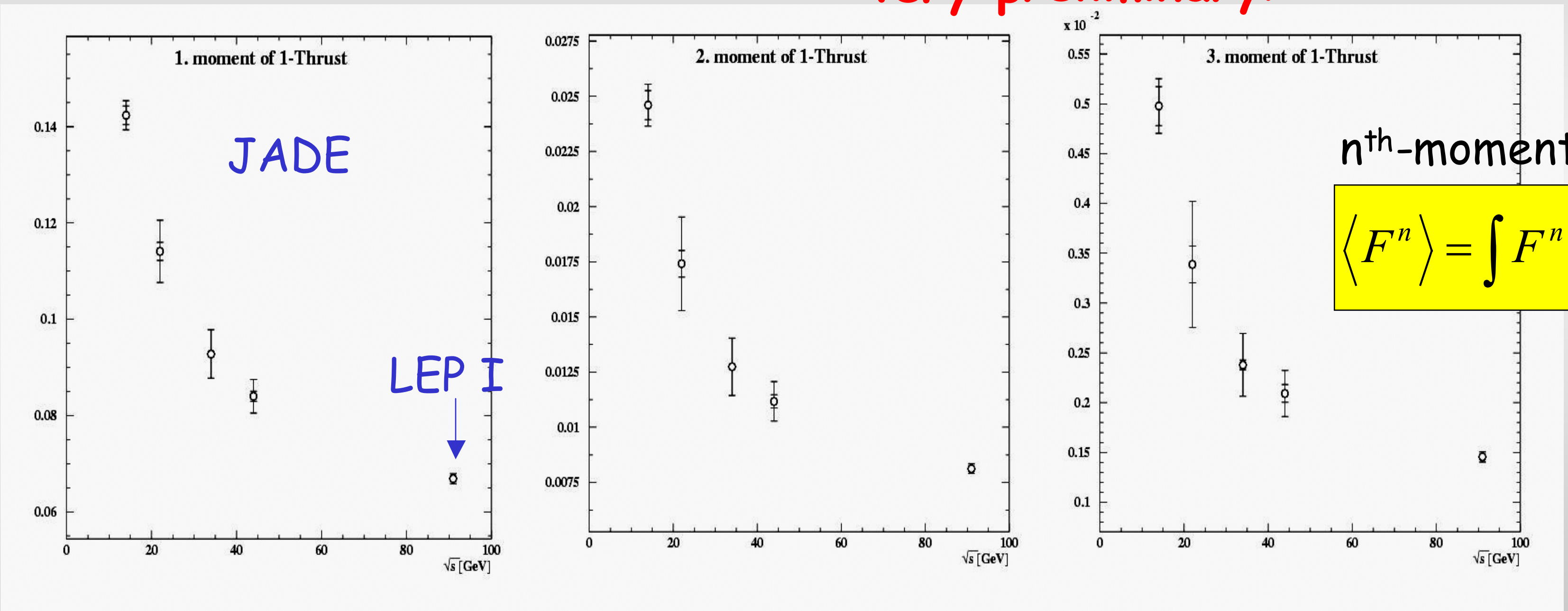
$$\xi_0 = \tfrac{1}{2} y + \sqrt{Cy} + C + O(y^{-1/2})$$

$$C = \frac{11 + \frac{2N_F}{27}}{24}\sqrt{\frac{48}{\beta_0}}$$

Outlook

- un-FPACK raw JADE data
- running of α_s using 1st-3rd moment and power corrections

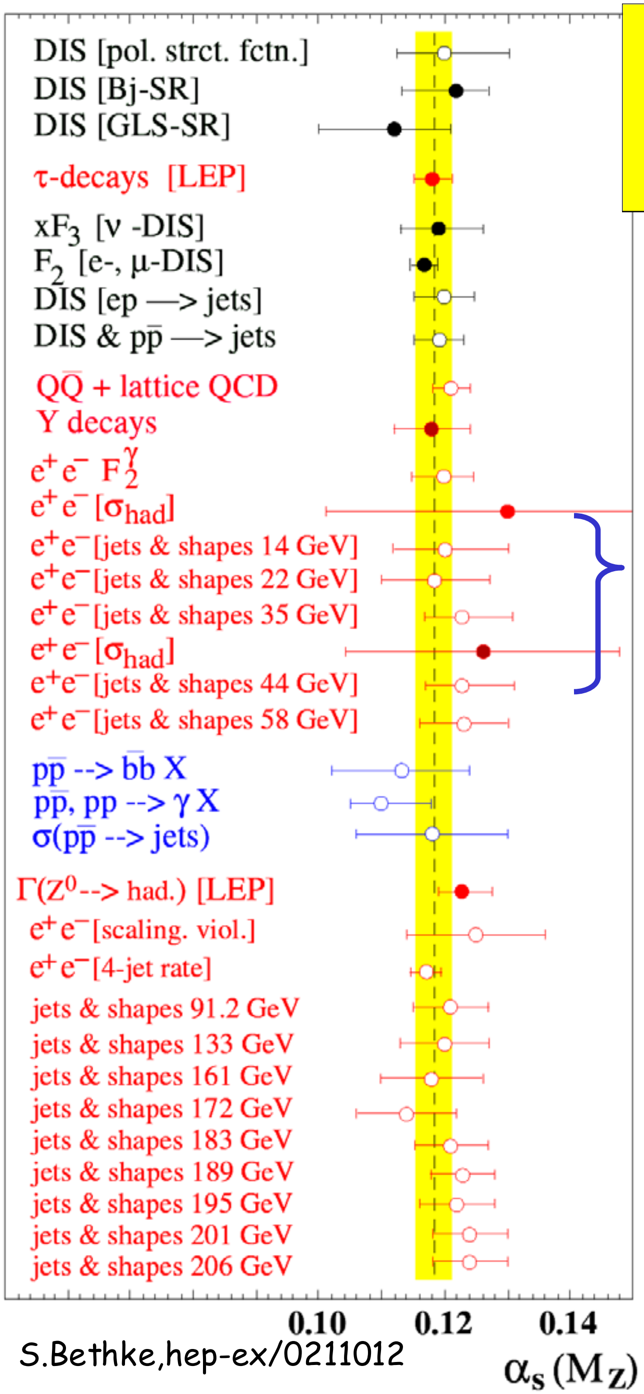
very preliminary!



n^{th}-moment:

$$\langle F^n \rangle = \int F^n \frac{d\sigma}{dF} dF$$

- measurement of α_s using 4-Jet events and $O(\alpha_s^3)$ calculations



S.Bethke,hep-ex/0211012

Conclusion (I)

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

$\alpha_s(M_{Z^\circ})=0.1194^{+0.0082}_{-0.0068}$ (PETRA)

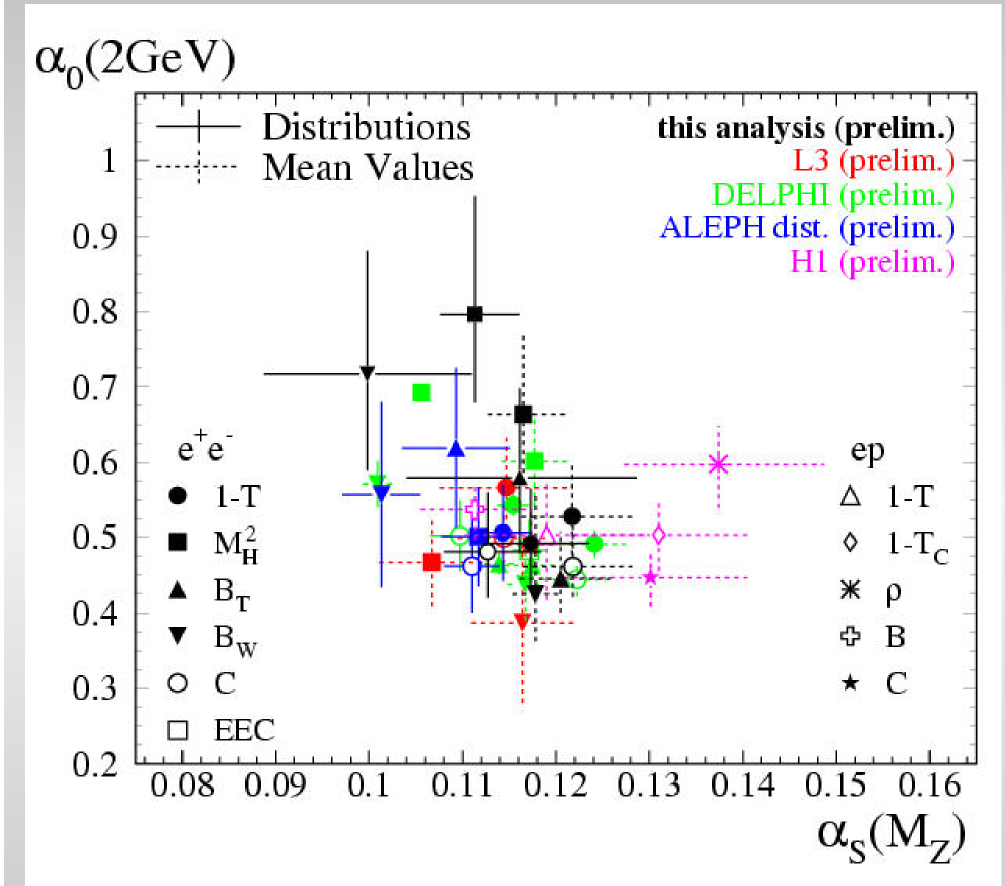
$\alpha_s(M_{Z^\circ})=0.121\pm0.006$ (LEP+SLC)

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

S.Bethke,hep-ex/0004021

consistent with other measurement and methods

Conclusion (II)



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

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

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

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

A Comment on archiving…

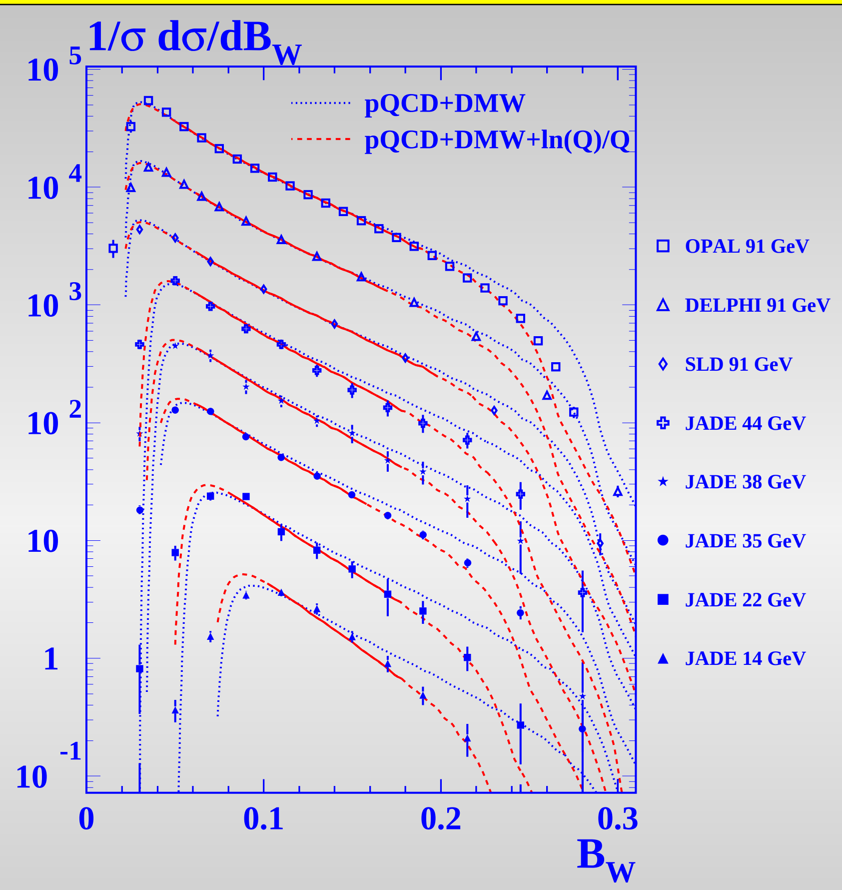
- archived data of finished experiments can provide valuable sources for future analysis
  - was the 'Pentaquark' already at LEP visible?
  - where was the $(D_s^+\pi^0)$ resonance before BaBar?
- no analysis without reconstruction software and the corresponding documentation (!)
- platform independent software simplifies running the code in the future
  - enforce the compilation and running of the software on several different machines

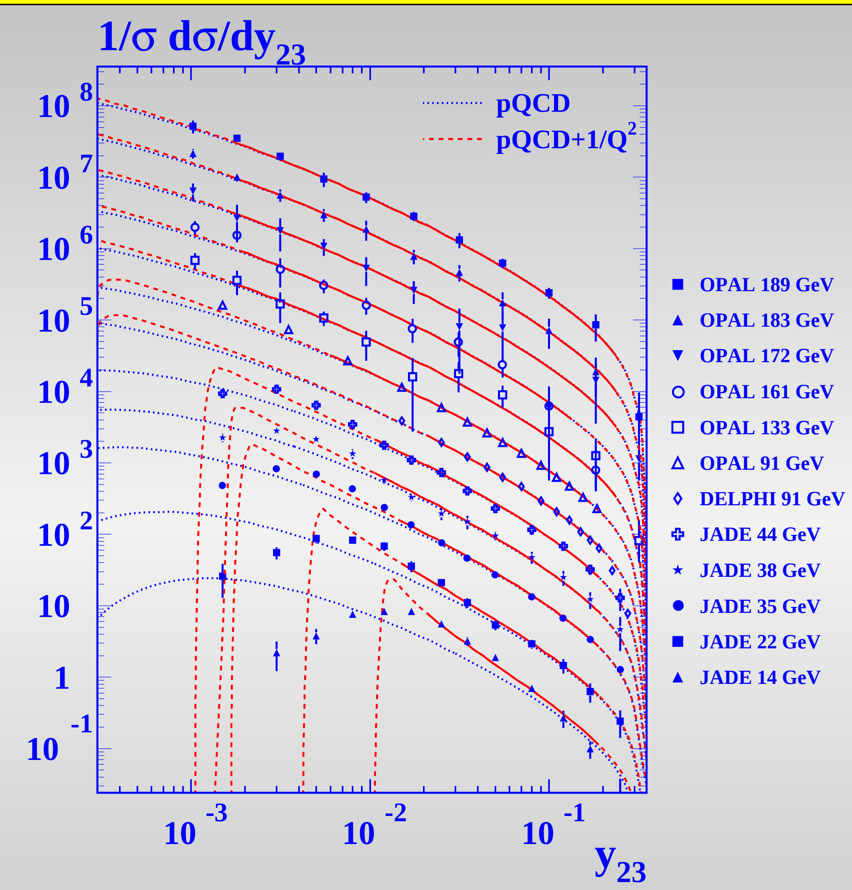
Conclusion

- data and software from the JADE experiment were successfully resurrected
- data was used to perform state-of-the-art QCD studies at $\sqrt{s} < M_{Z^0}$
- results provide stringent tests of perturbative and non-perturbative aspects of QCD
- Keep the data and software alive, it's worth it

Backup Slides

Power Correction

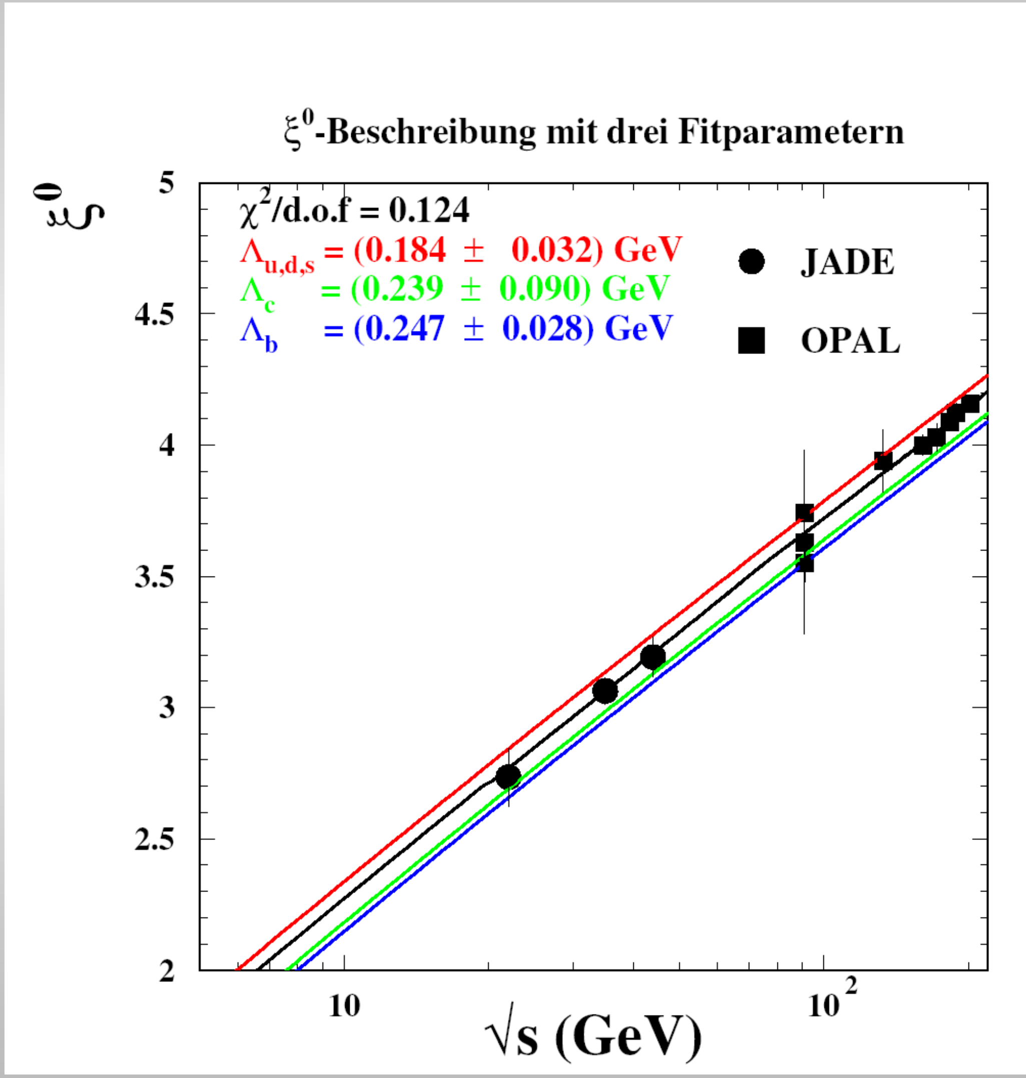




Log. Enhancement ~ lnQ/Q
yields better description of data

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

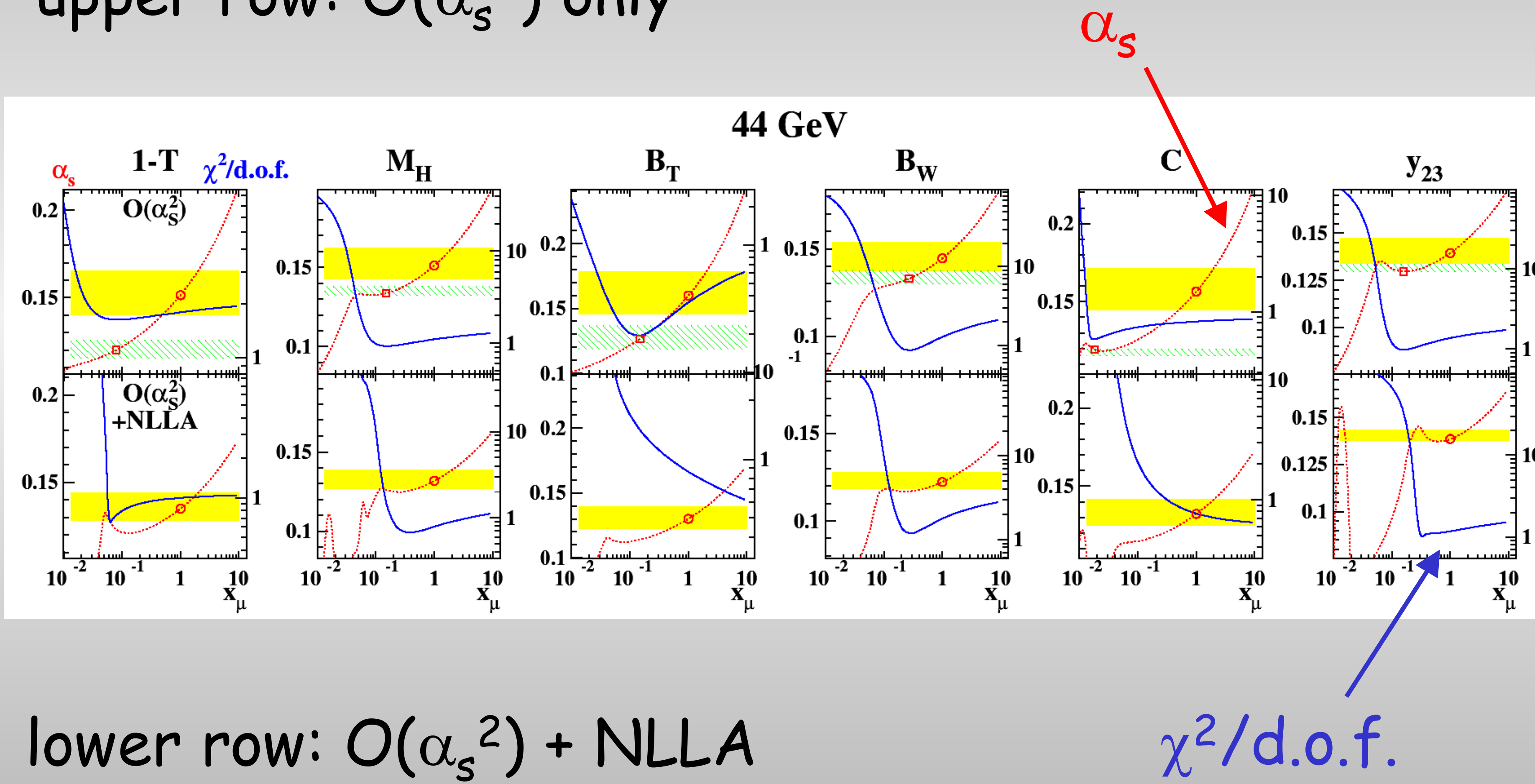
Flavor Dependence



- determine Λ_b and Λ_c from flavour composition and direct measurement at the Z^0

Renormalisation Scale

upper row: $O(\alpha_s^2)$ only



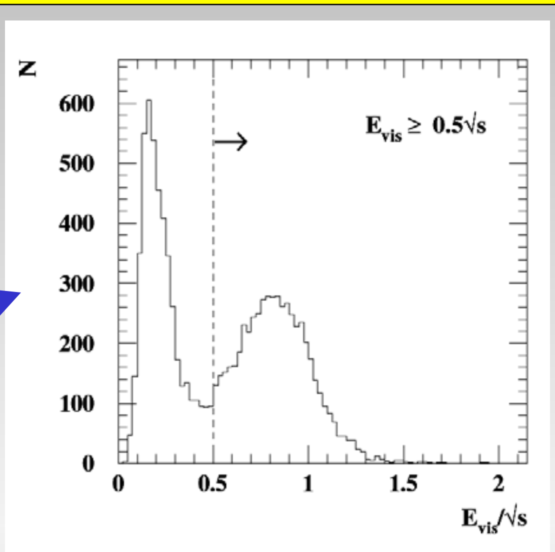
lower row: $O(\alpha_s^2)$ + NLLA

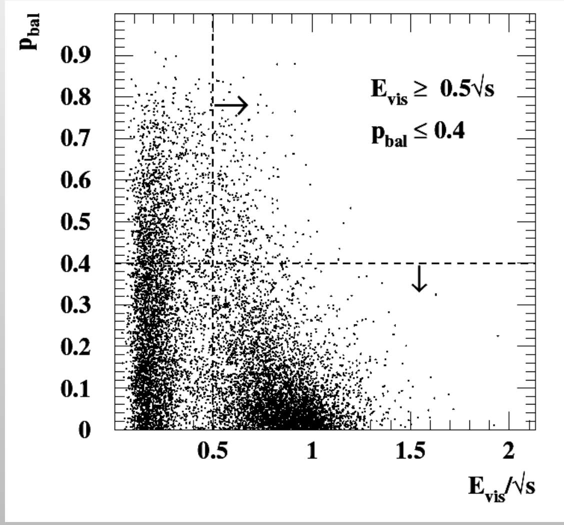
Hadronic Event Selection

- main selection cuts:
  - 4 tracks from vertex region
  - 3 'long+good' tracks
  - visible energy > 0.5 $\sqrt{s}$
  - momentum balance < 40%
  - missing momentum < 0.3 $\sqrt{s}$
  - $|\cos\Theta_{T}| < 0.8$

residual background ~ 1%:

- $e^+e^- \rightarrow e^+e\,\gamma\gamma$
- $e^+e^- \rightarrow \tau^+\tau^-$





JADE vs OPAL Experiment

	Parameter		JADE	OPAL
Dimensions	overall length		8 m	12 m
	overall height		7 m	12 m
Tracking system	dimension	length	2.4 m	4 m
		outer radius	0.8 m	1.85 m
	transv. momentum	A	0.04	0.02
	resolution $\sigma(p_t)/p_t$	B	0.018	0.0015
	spatial	$r-\phi$	180 μm/110 μm	135 μm
	resolution	z	1.6 cm	4.5—6 cm (100—350μm)
	double hit resol.		7.5 mm/2 mm	2.5 mm
	gas composition argon/methane/isobutane		88.7%/8.5%/2.8%	88%/9.4%/2.6%
	gas pressure		4 bar	4 bar
	max. no. of hits		48	159
	reachable in		$0.83 \cdot 4\pi$	$0.73 \cdot 4\pi$
	at least 8 hits reachable in		$0.97 \cdot 4\pi$	$0.98 \cdot 4\pi$
	magnetic field		0.48 T	0.435 T
Electromagnetic calorimetry	energy	A	0.015	0.002
	resolution $\sigma(E)/E$	B	0.04	0.063
	solid angle coverage		90%	98%
	angular resolution		7 mrad	2 mrad
	barrel	radial extent	1—1.4 m	2.5—2.8 m
		length	3.6 m	7 m
		polar angle covered	$> 32^o$	$> 36^o$
		radiation depth	$12.5X_0/15.7X_0$	$24.6X_0$
		granularity	8.5×10 cm^2	10×10 cm^2
	endcap	outer radius	0.9 m	1.8 m
		polar angle covered	$> 11^o$	$> 11^o$
		radiation depth	$9.6X_0$	$22X_0$
		granularity	14×14 cm^2	9×9 cm^2