

MAGNETDETEKTOR
MAGNET DETECTOR

QCD Studies with resurrected JADE Data

1 Strahlrohrzähler STRAHLENTUBES
2 Endseitige Bleiglaszähler END-TUBULAR GLASS COUNTERS
3 Druckkammern PRESSURE CHAMBERS
4 Myon-Kammern MUON CHAMBERS
5 Tet-Kammern TETRAPOLES
6 Flugzeit-Zähler TIME-OF-FLIGHT COUNTERS
7 Spule COIL
8 Zentrale Bleiglaszähler CENTRAL TUBULAR GLASS COUNTERS
9 Magnetjoch MAGNET YOK
10 Myon-Filter MUON FILTERS
11 Beweglicher Endstopfen REMOVABLE END-PLUG

Outline:

- 1 Introduction
- 2 Data vs modern MCs
- 3 Scaled Momentum $\xi = \ln(1/x)$
- 4 Extended Power Correction Fits

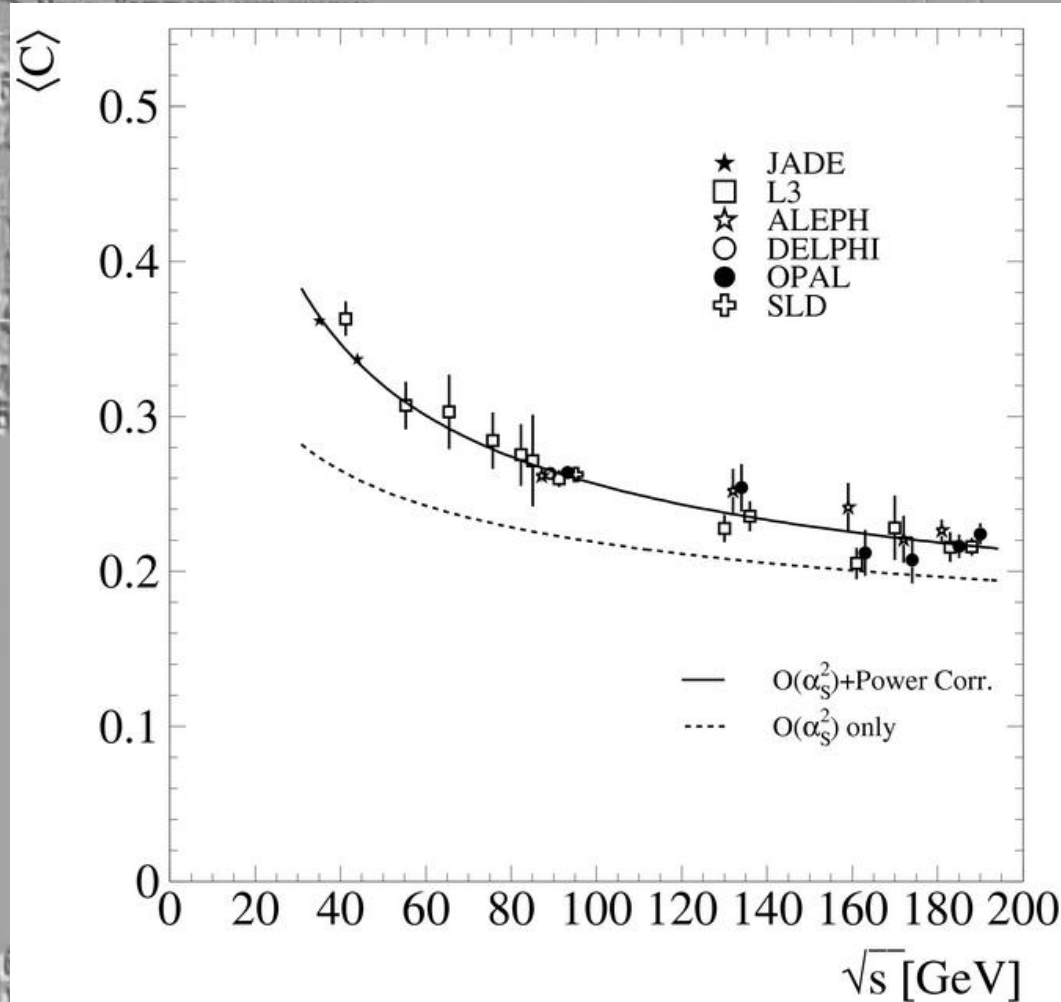
Stefan Kluth

for M. Blumenstengel, P. A.
Movilla Fernandez, S. Bethke,
O. Biebel, C. Pahl, J. Schieck

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Gesamtgewicht TOTAL WEIGHT: 1200 t
Magnetfeld MAGNETIC FIELD: 0.5 T
Beteiligte Institute PARTICIPANTS
DESY, Hamburg, Heidelberg,
Lancaster, Manchester,
Rutherford Lab., Tokio

1 Why low energy e^+e^- data?



Running strong coupling:

$$\alpha_s(Q) = \alpha_s(\mu) / (1 + 2\beta_0 \ln(Q/\mu))$$

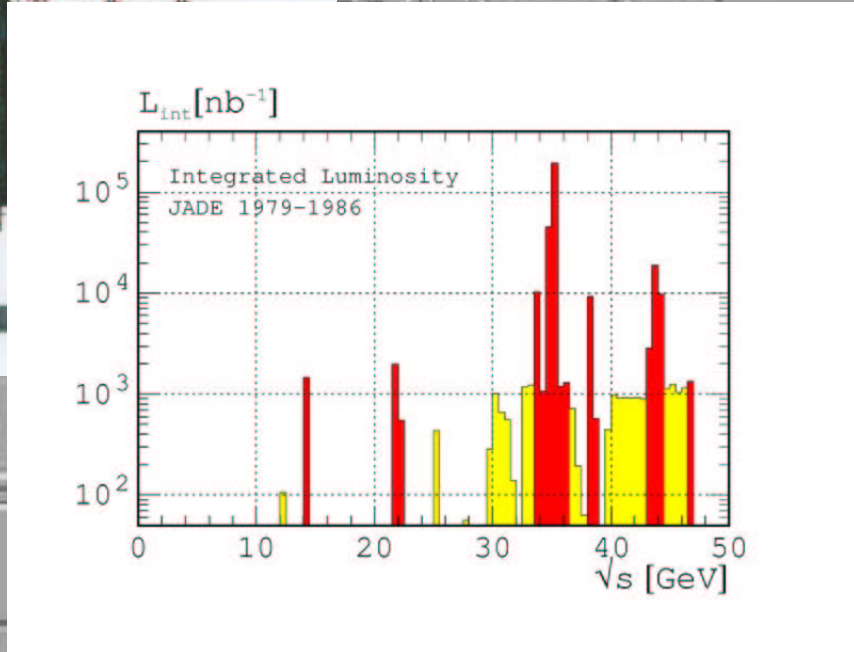
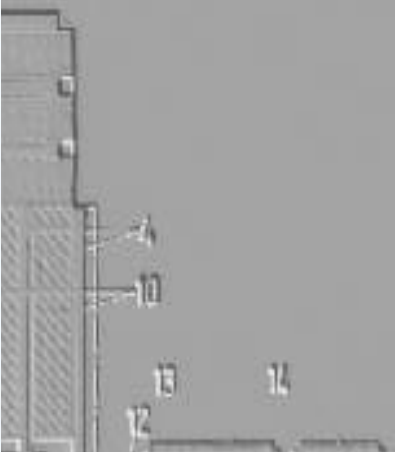
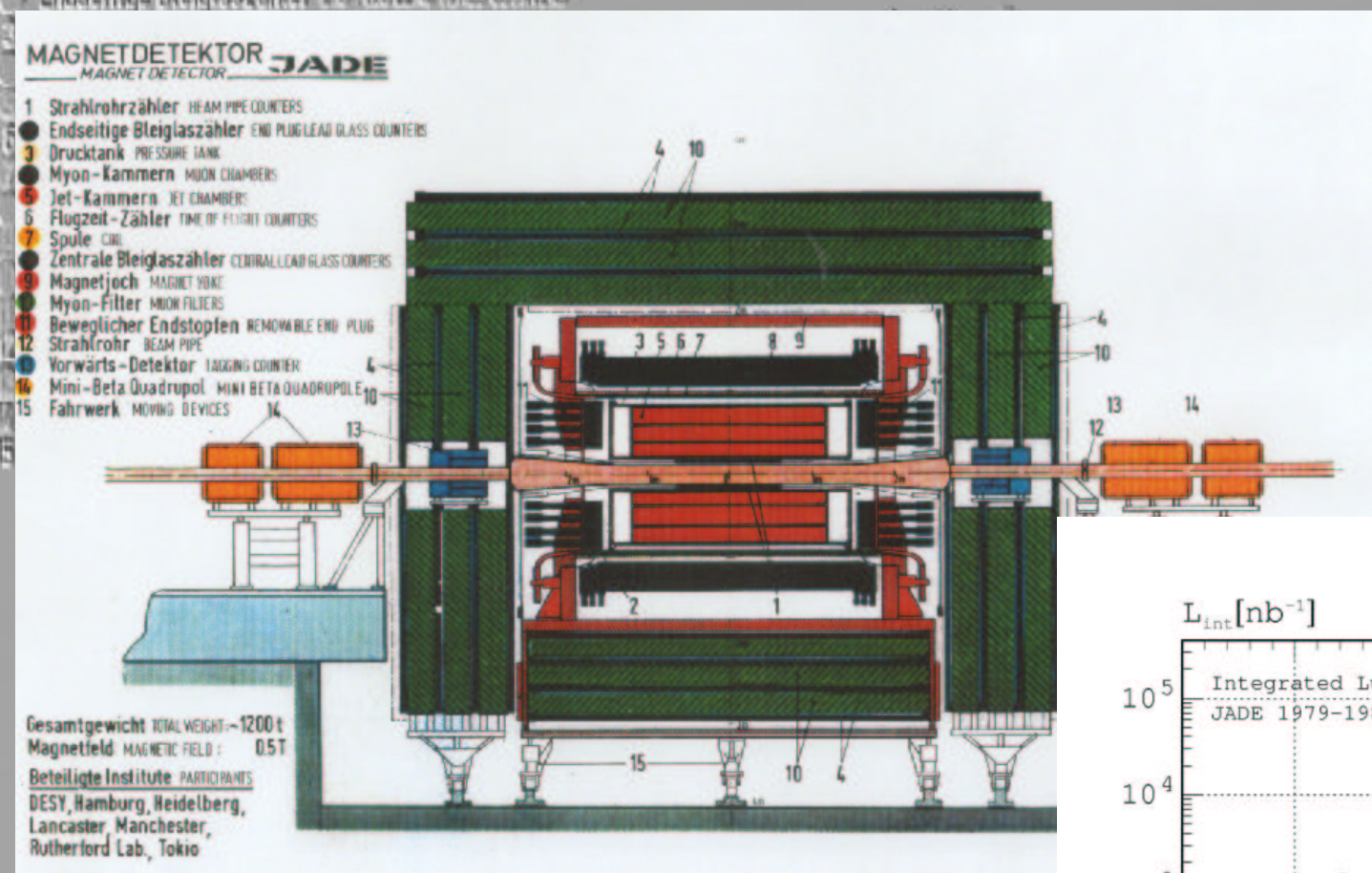
$$\langle C \rangle = A_c \alpha_s(Q) + B_c \alpha_s^2(Q) + P_c/Q$$

→ Interplay between hard and soft QCD best studied at 'medium' energies

→ JADE data!

Eur. Phys. J. C22 (2001) 1-15

1 The JADE Detector and Data



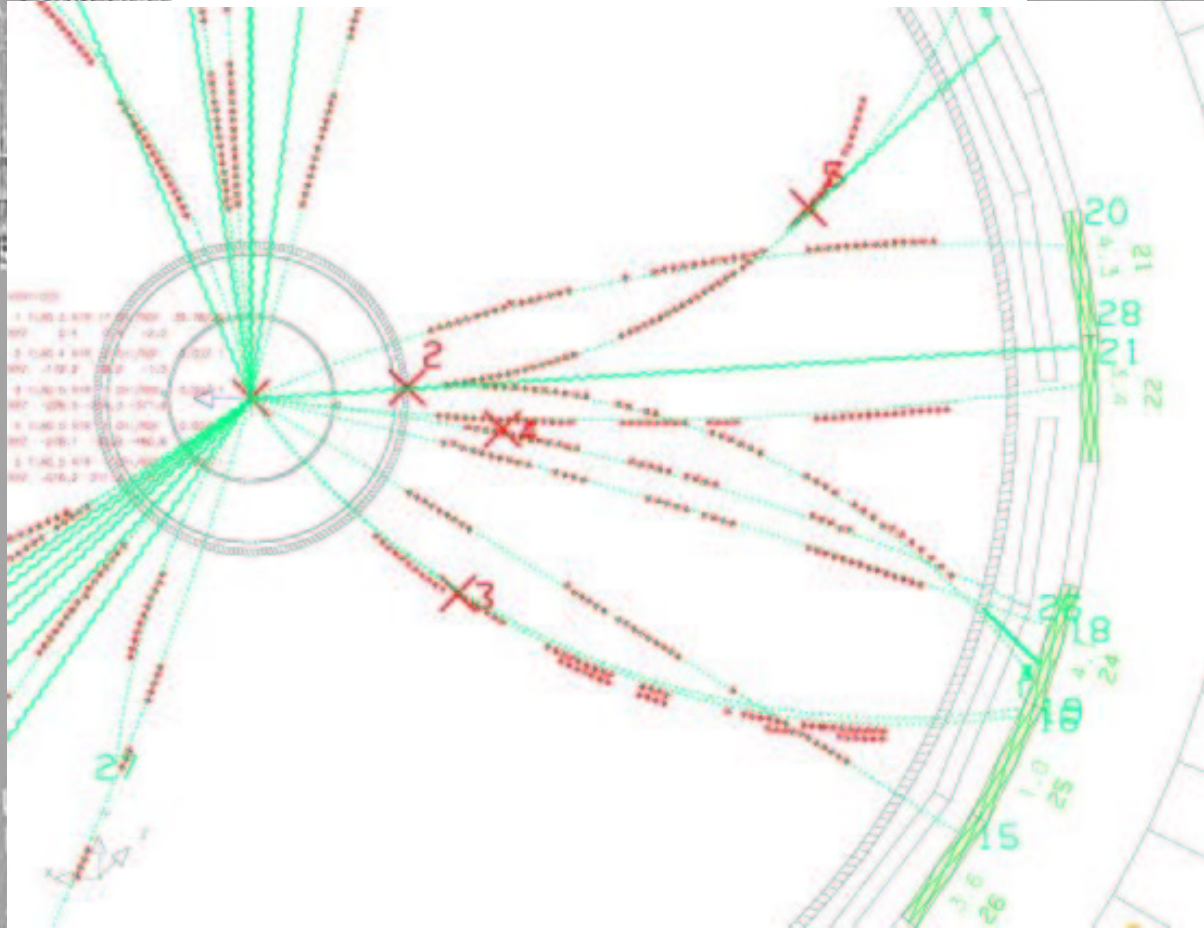
JADE @ PETRA/DESY 1979 - 1986
 $\sqrt{s} = 12$ to $46,8$ GeV

Gesamtgewicht
Magnetfeld
Beteiligte Institute
DESY, Hamburg, Heidelberg,
Lancaster, Manchester,
Rutherford Lab., Tokio

1 The JADE Software

- 1 Strahlrohrzähler STRAWPIPE COUNTERS
- 2 Endseitige Bleiglaszähler END FLUORESCENT GLASS COUNTERS
- 3 Druckkammern PRESSURE CHAMBERS
- 4 Neon-Kammern NEON CHAMBERS
- 5 Tet-Kammern TET CHAMBERS
- 6 Flugzeit-Zähler TIME-OF-FLIGHT COUNTERS
- 7 Spule COIL
- 8 Zentralkammer ZENITHAL CHAMBER

Hadronic event in JADE at 35 GeV



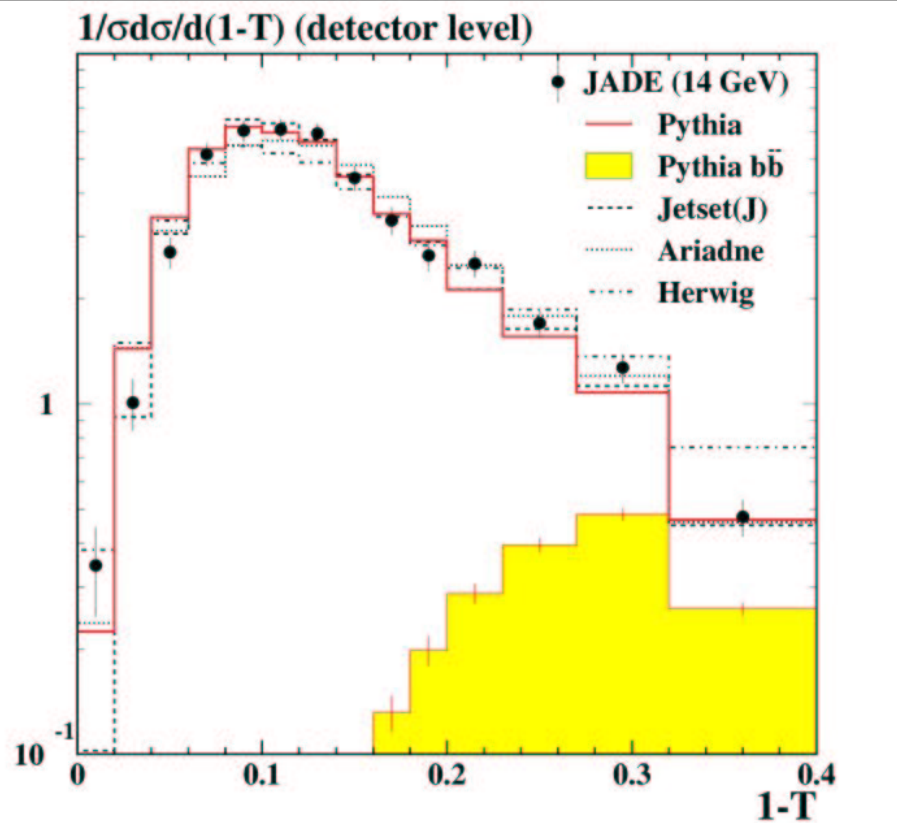
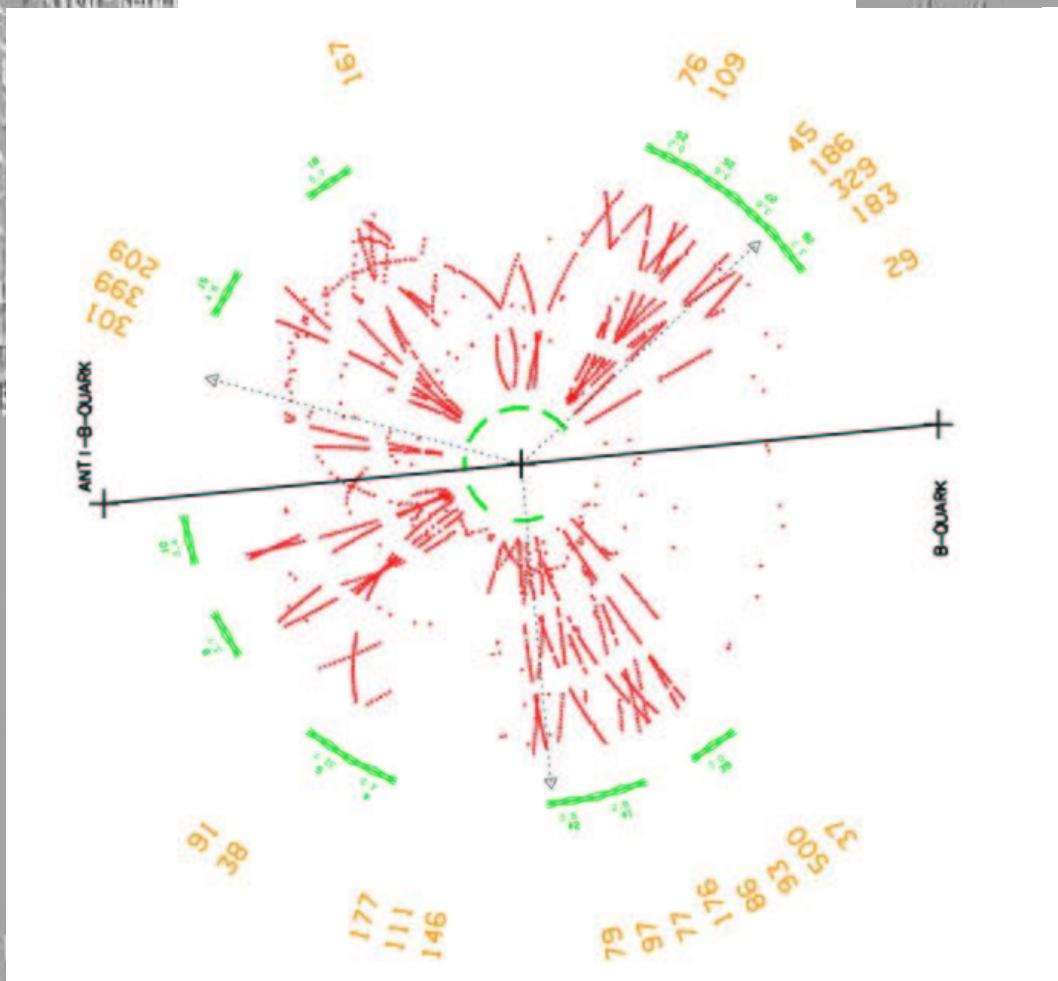
Detector simulation (pre-GEANT) and reconstruction running on IBM RS6000 AIX system

- ➔ generate physics using modern generators, e.g. PYTHIA, HERWIG, ARIADNE (LEP 1 tunes)
- ➔ pass through JADE simulation/reconstruction
- ➔ compare with data or derive corrections

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2 Background from b-production

PYTHIA b-event at 14 GeV



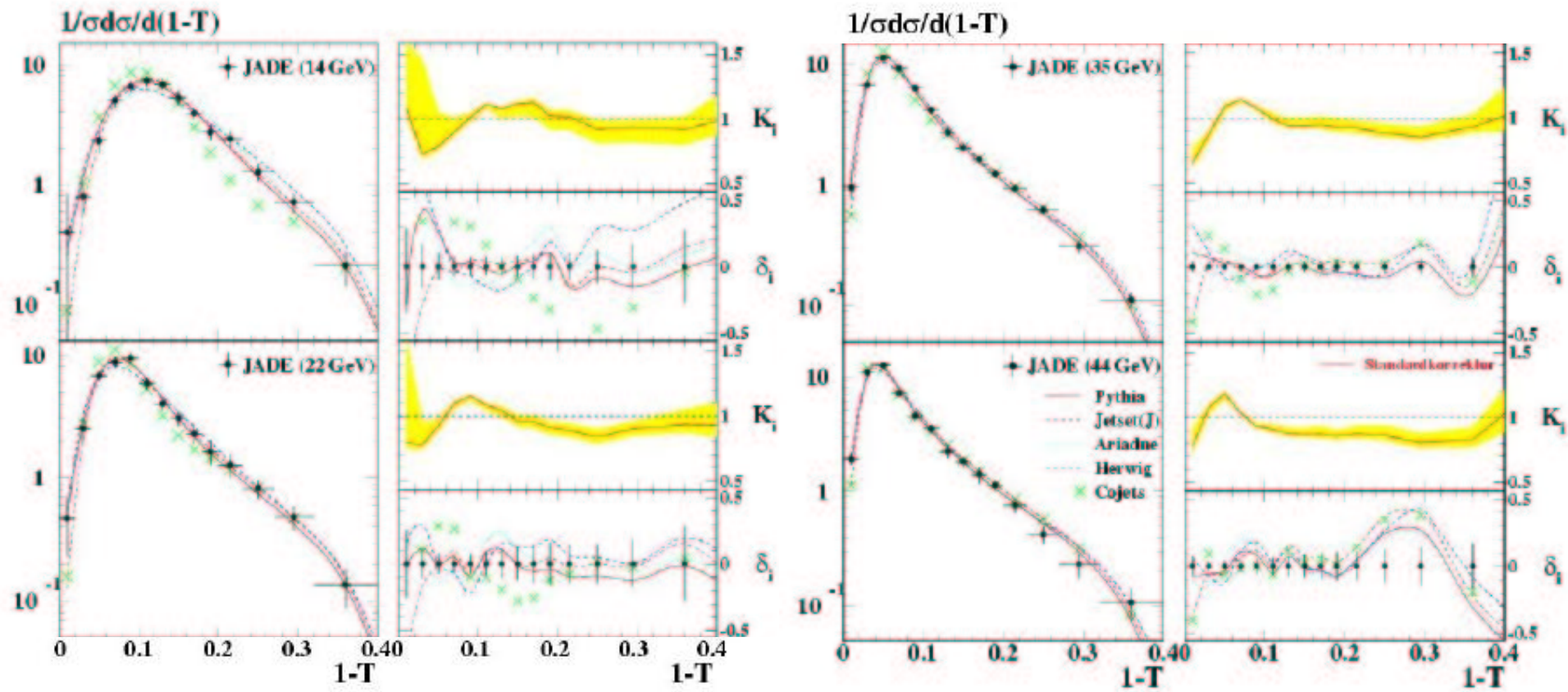
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Subtract b-background (~9%), present data at udsc hadron-level

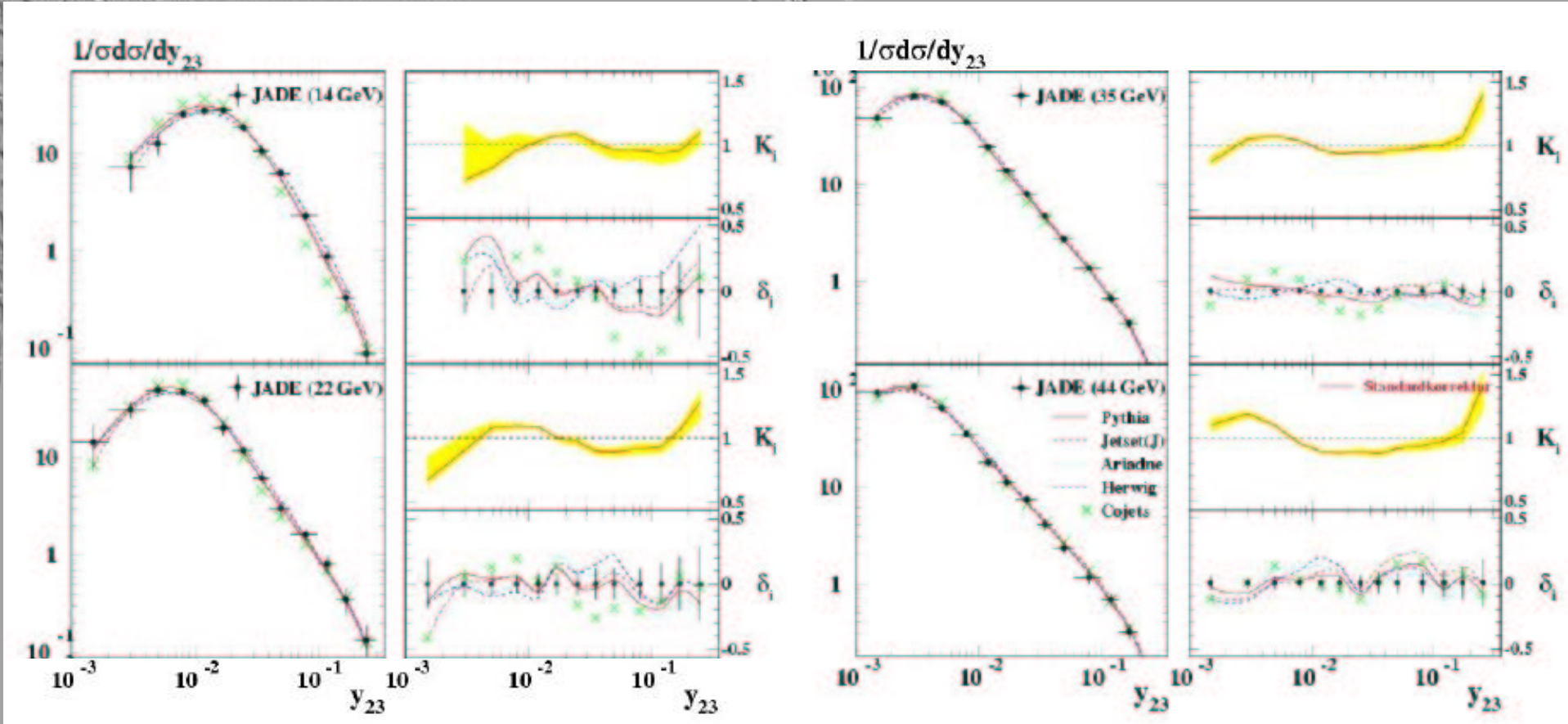
2 JADE Data vs MC: Thrust

Generators: **PYTHIA 5.7**, **HERWIG 5.9**, **ARIADNE 4.08**, **COJETS 6.23**
with OPAL (-based) LEP 1 tunes, **JETSET 6.3** with JADE tune

Data at hadron-level corrected for bb-background



2 JADE Data vs MC: y_{23} (Durham)



PYTHIA/ARIADNE generally ok, HERWIG too hard at low \sqrt{s} ,
JETSET6.3(J) ok too, COJETS fails at low \sqrt{s}

3 Scaled momentum $\xi = \ln(1/x)$

Shape of $\xi = \ln(1/x)$ distribution around peak: **skewed Gaussian**

MLLA ($Q_0 \approx \Lambda$) calculation for partons \rightarrow LPHD \rightarrow hadron spectra

$$D_{(\xi)} = \frac{N(\mathbf{y})}{\sqrt{2\pi\sigma(\mathbf{y})}} \exp\left(\frac{\mathbf{k}(\mathbf{y})}{8} - \frac{\mathbf{S}(\mathbf{y})\delta}{2} + \frac{(2 + \mathbf{k}(\mathbf{y}))\delta^2}{4} + \frac{\mathbf{S}(\mathbf{y})\delta^3}{6} + \frac{\mathbf{k}(\mathbf{y})\delta^4}{24}\right)$$

$$\delta = (\xi - \langle \xi \rangle(\mathbf{y})) / \sigma(\mathbf{y}), \quad \mathbf{y} = \log \frac{\sqrt{s}}{2\Lambda_{eff}}, \quad \xi^0 - \langle \xi \rangle \simeq \frac{(11 - 2n_f)/9}{32C_A}, \quad \langle \xi \rangle = \mathbf{F}(\mathbf{y}) + \mathbf{O}(1)$$

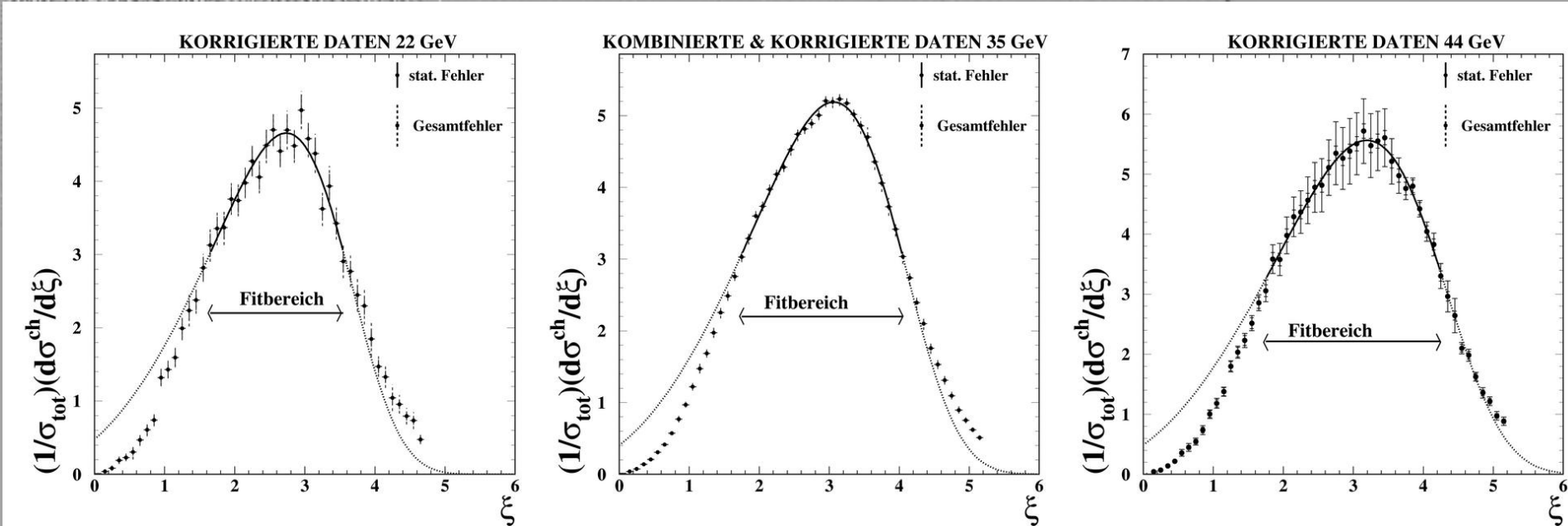
$$\mathbf{S} = \langle (\xi - \langle \xi \rangle)^3 \rangle / \sigma^3, \quad \mathbf{k} = \langle (\xi - \langle \xi \rangle)^4 \rangle / \sigma^4 - 3$$

Nucl. Phys. B355 (1991) 54

3 Measurements and Fits

- 1. Strahlrohrzähler STRAW TUBES
- 2. Endseitige Bleiglaszähler END FLUORESCENT GLASS COUNTERS
- 3. Druckkammern PRESSURE CHAMBERS
- 4. Nyon-Kammern NYON CHAMBERS
- 5. Tet-Kammern TET CHAMBERS
- 6. Flugzeit-Zähler TIME-OF-FLIGHT COUNTERS
- 7. Spule COIL
- 8. Zeitstempel-Zähler TIME STAMP COUNTERS

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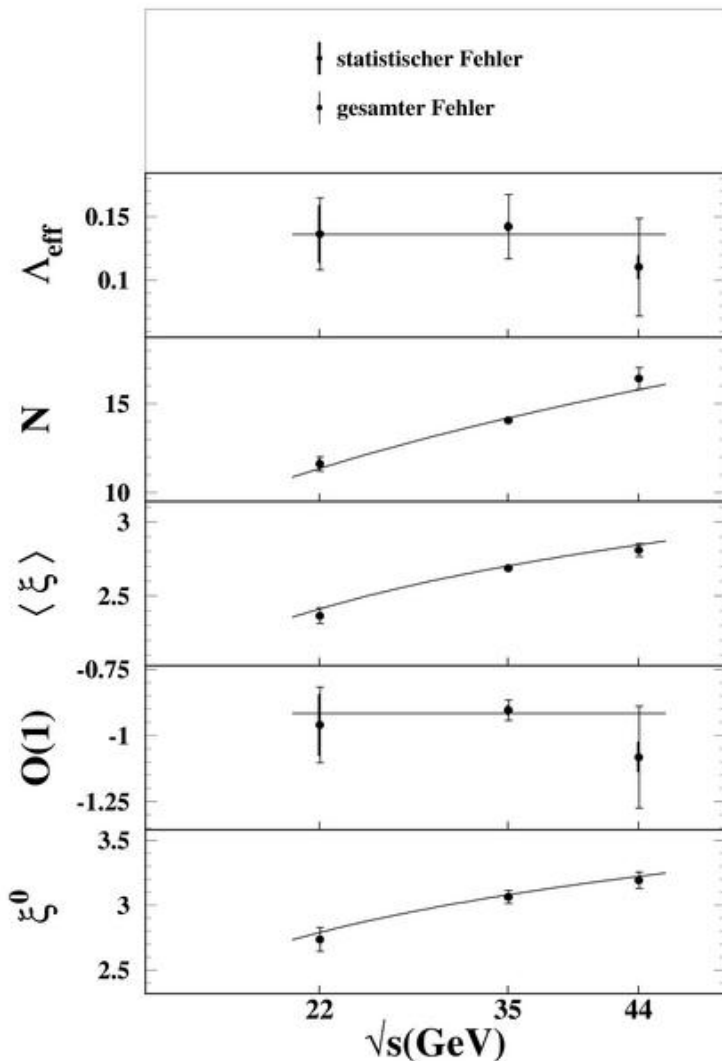


Fit MLLA (Fong/Webber): Λ_{eff} , N , and $\langle \xi \rangle$, $O(1)$ or ξ^0
 \rightarrow results for Λ_{eff} , N stable w.r.t. $\langle \xi \rangle$, $O(1)$ or ξ^0

3 Peak Fit Results

1. Strahlrohrzähler SPAN/GEIGER COUNTERS
2. Endseitige Bleiglaszähler END FLUORESCENCE COUNTERS
3. Druckkamm PRESSURE TANK

Fitparameter mit statistischen und gesamten Fehlern



Peak position $\langle \xi \rangle$ or ξ^0 and N depend on \sqrt{s}

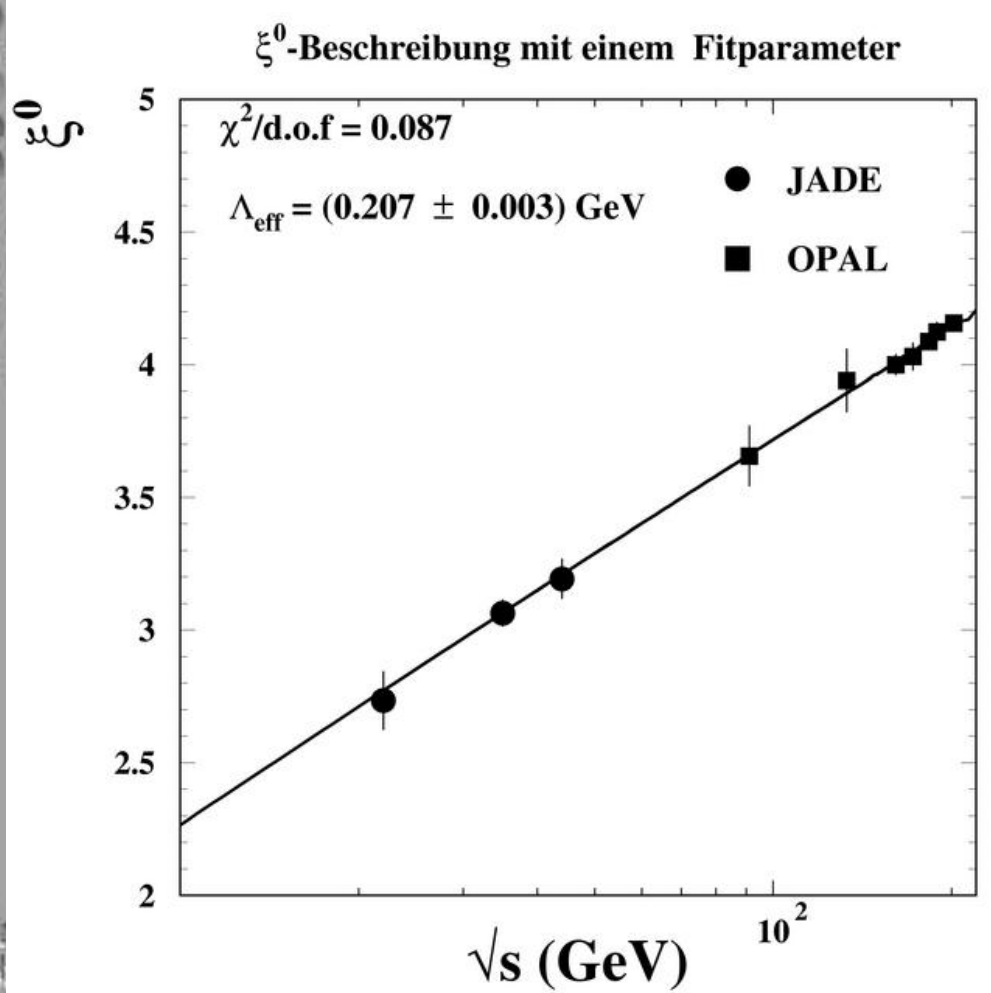
Λ_{eff} and $O(1)$ constant

\sqrt{s} [GeV]	ξ^0	N	Λ_{eff} [MeV]
22	2.74 ± 0.09	11.6 ± 0.4	136 ± 28
35	3.06 ± 0.05	14.1 ± 0.2	142 ± 25
44	3.19 ± 0.06	16.4 ± 0.6	110 ± 38

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3 MLLA Peak Position Fits

- 1. Strahlrohrzähler STRAHLENGÄHRE
- 2. Endseitige Bleiglaszähler ENDSEITIGES BLEIGLASSCHÜTTENS
- 3. Druckbank DRUCKBANK
- 4. Nyon-Kammern NYON-KAMMERN



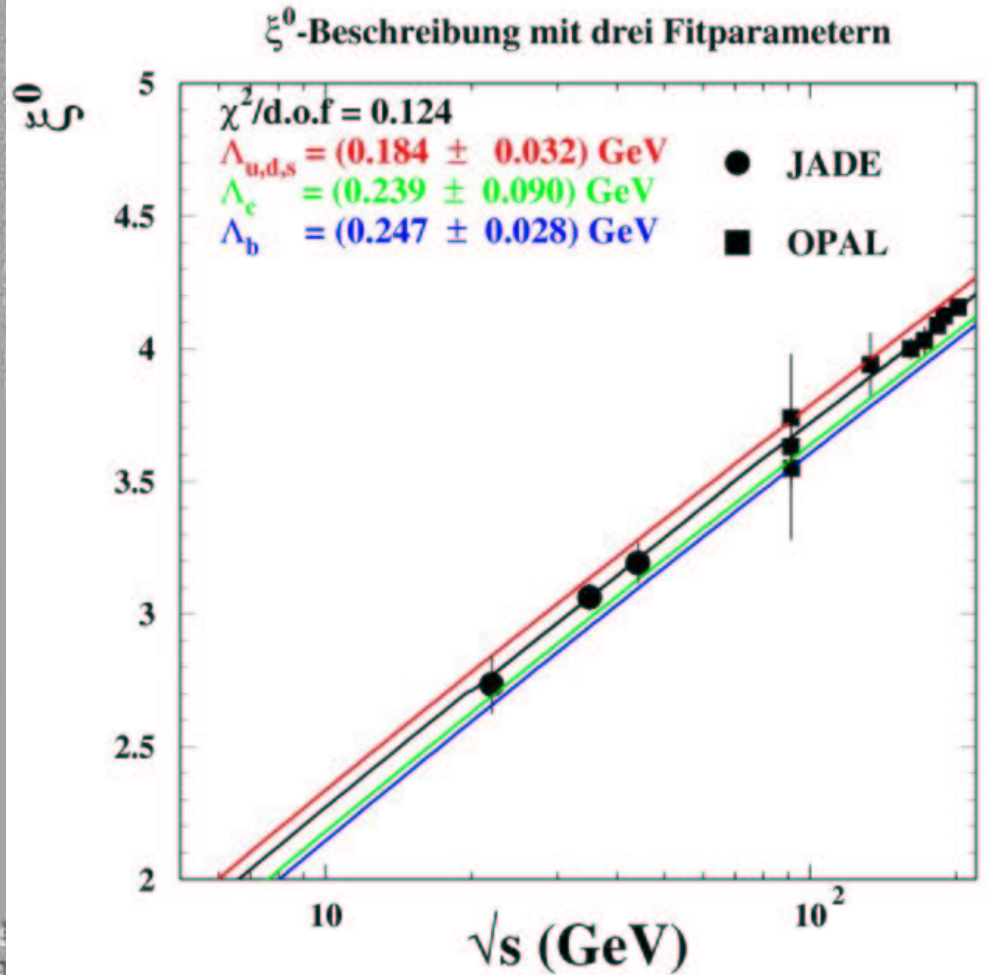
$$\xi^0(\mathbf{y}) = \frac{1}{2} \mathbf{y} + \sqrt{C\mathbf{y}} + C$$

$$\mathbf{y} = \log \frac{\sqrt{s}}{2 \Lambda_{\text{eff}}}$$

$$\Lambda_{\text{eff}} = 206 \pm 3 \text{ MeV}$$

Reasonable description of data
(similar result from OPAL)

3 Flavour (Mass) Effects



$$\xi_{c,b}^0 \approx \xi_{uds}^0 + 0.5 \log \left(\frac{\Lambda_{c,b}}{\Lambda_{uds}} \right)$$

Fit with Λ_b , Λ_c and Λ_{uds} with data from OPAL for ξ_b^0 , ξ_c^0 and ξ_{uds}^0 as constraints

$$\Lambda_{uds} = 184 \pm 33 \text{ MeV}$$

$$\Lambda_c = 239 \pm 90 \text{ MeV}$$

$$\Lambda_b = 247 \pm 28 \text{ MeV}$$

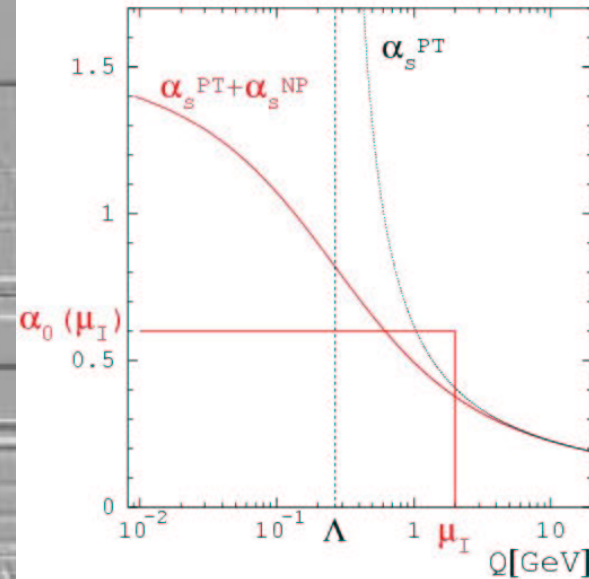
Mass effects about 20–30%

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4 Extended Power Correction Fits

DMW model:

- assume integrable α_s at very low Q
- analyse renormalon ambiguities



$$\langle y \rangle = \langle y \rangle_{PT} + D_y P$$

$$\frac{d\sigma}{dy} = \frac{d\sigma_{PT}}{dy} (y - D_y P)$$

$$P \approx M \frac{\mu_I}{Q} (\alpha_0(\mu_I) - \alpha_S(\mu_R))$$

$$\alpha_0(\mu_I) = \frac{1}{\mu_I} \int_0^{\mu_I} \alpha_S(k) dk$$

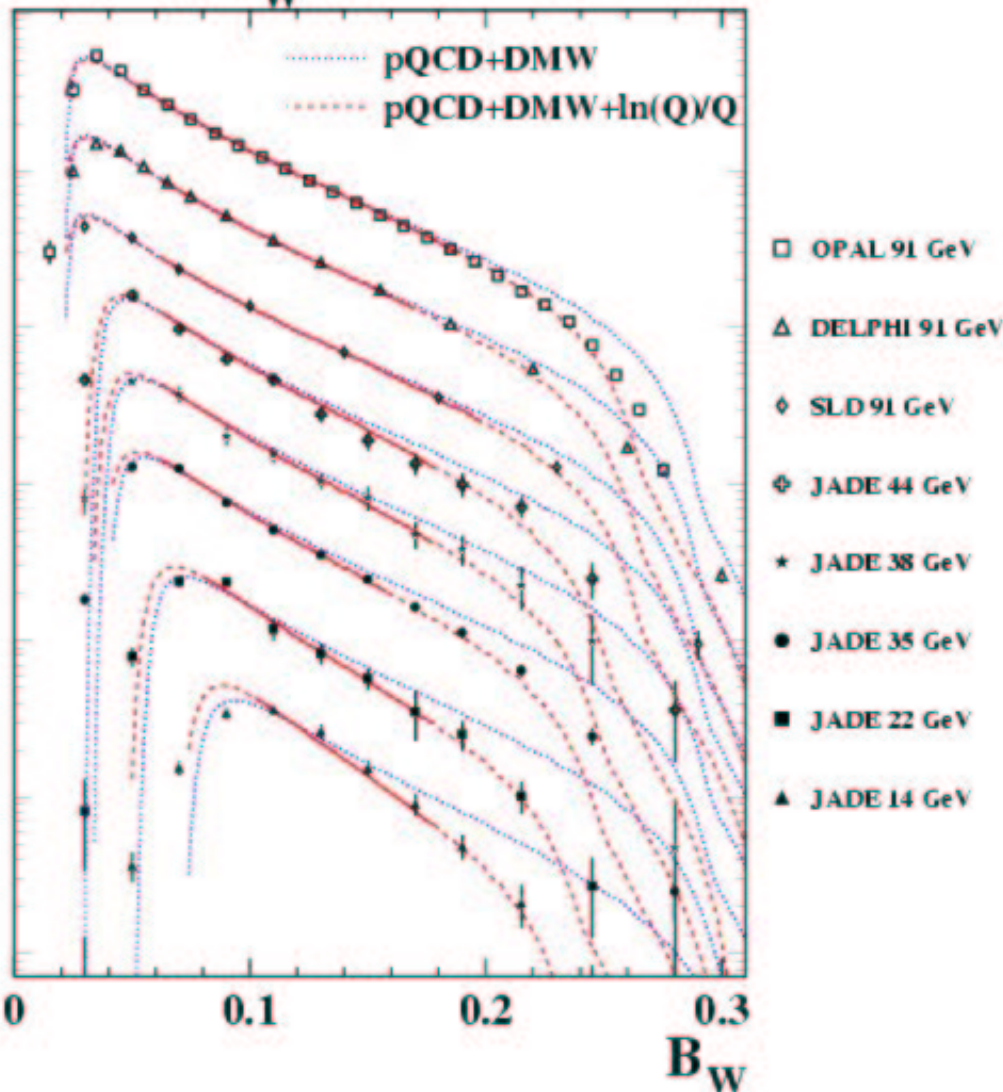
y	D_y
$1 - T$	2
M_H^2	1
C	3π
B_T	$\ln(1/B_T) + D_{B_T}(B_T, \alpha_S)$
B_W	$\frac{1}{2} \ln(1/B_W) + D_{B_W}(B_W, \alpha_S)$

DESY, Hambg Nucl. Phys. B469 (1996) 93

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4 Extended Fits with B_W

$1/\sigma d\sigma/dB_W$



pQCD is $O(\alpha_s^2)$ +NLLA, $\sqrt{s} < M_Z$

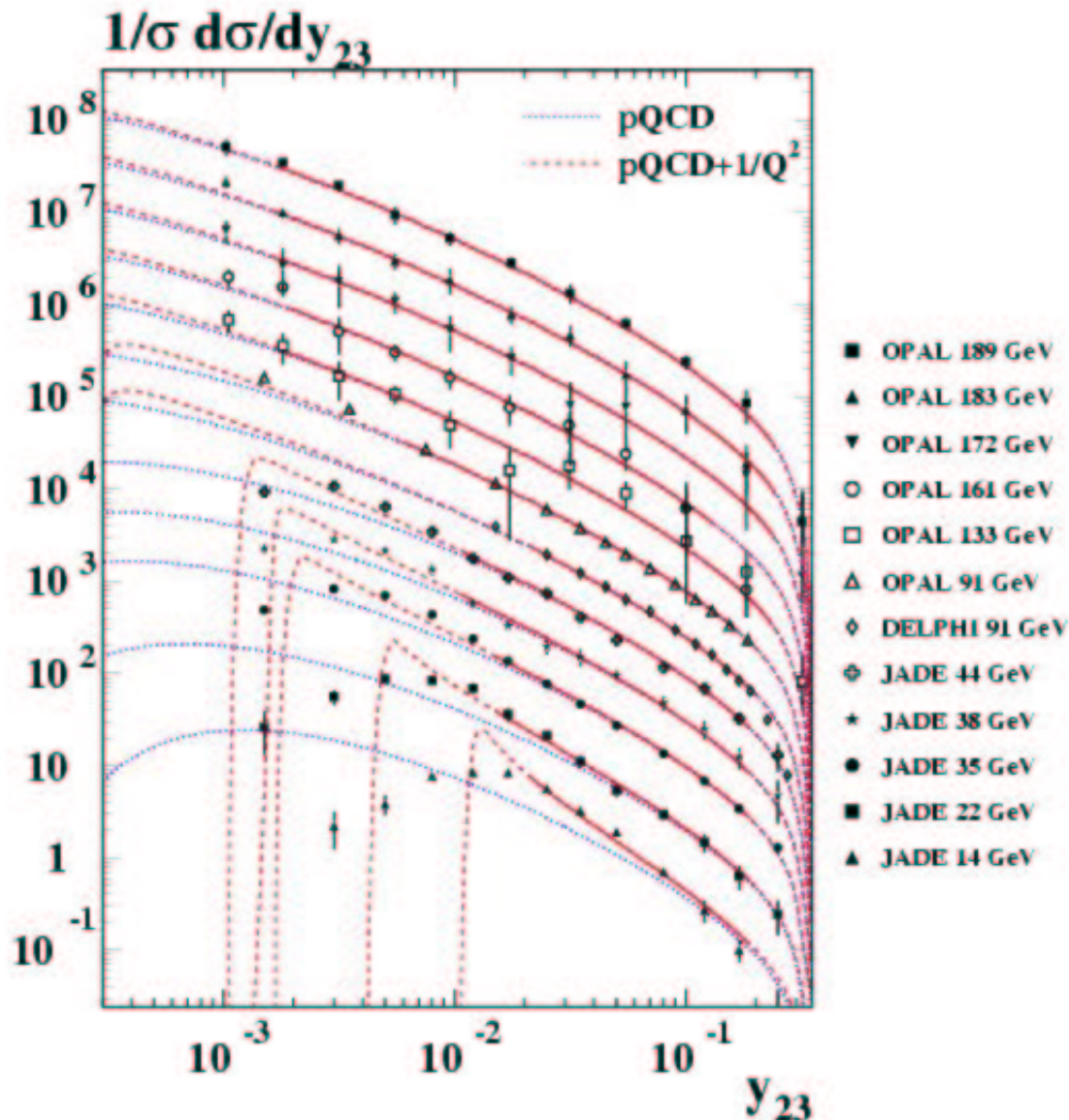
$$\chi^2(\text{pQCD+DMW}) = 65.5/24$$

$$\chi^2(\text{pQCD+DMW}+A_{11}) = 22.2/23$$

Evidence for additional terms,
probably behaving like $\ln(Q)/Q$

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4 Extended Fits with $y_{23}(D)$



pQCD is $O(\alpha_s^2) + \text{NLLA}$

⇒ extended fit ranges

⇒ DMW prediction is $\langle y_{23} \rangle \sim \ln(Q)/Q^2$

$$\chi^2(\text{pQCD}) = 151/107$$

$$\chi^2(\text{pQCD} + A_{20}/Q^2) = 71.2/106$$

Evidence for additional terms, probably behaving like $1/Q^2$ at low \sqrt{s}

Analysis with restricted fit ranges is consistent too

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Summary

- Modern MC generators with LEP 1 tunes generally agree with JADE data down to 14 GeV
 - Quantitative QCD studies at 14 to 44 GeV
 - Ideal laboratory for interplay hard \leftrightarrow soft QCD
- Measured $\xi = \ln(1/x)$ 22 to 44 GeV with JADE
 - Test MLLA QCD predictions (together with OPAL)
 - Study flavour (mass) effects (together with OPAL)
- Extended DMW power corrections fits
 - $B_W \rightarrow$ additional $A_{11} \ln(Q)/Q$ contribution?
 - $y_{23}(D) \rightarrow$ additional A_{20}/Q^2 contribution?