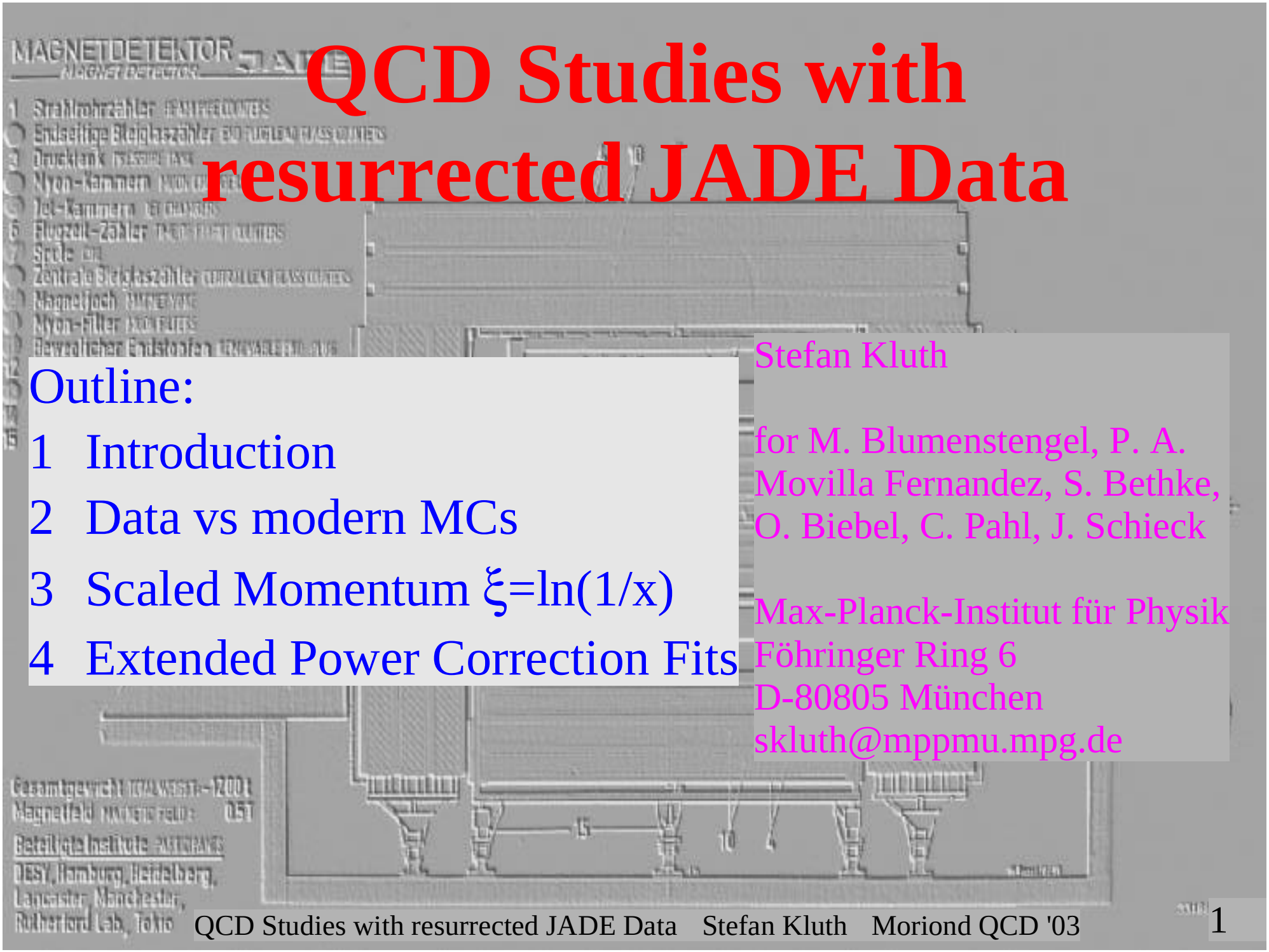
QCD Studies with resurrected JADE Data



Outline:

1 Introduction

2 Data vs modern MCs

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

4 Extended Power Correction Fits

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

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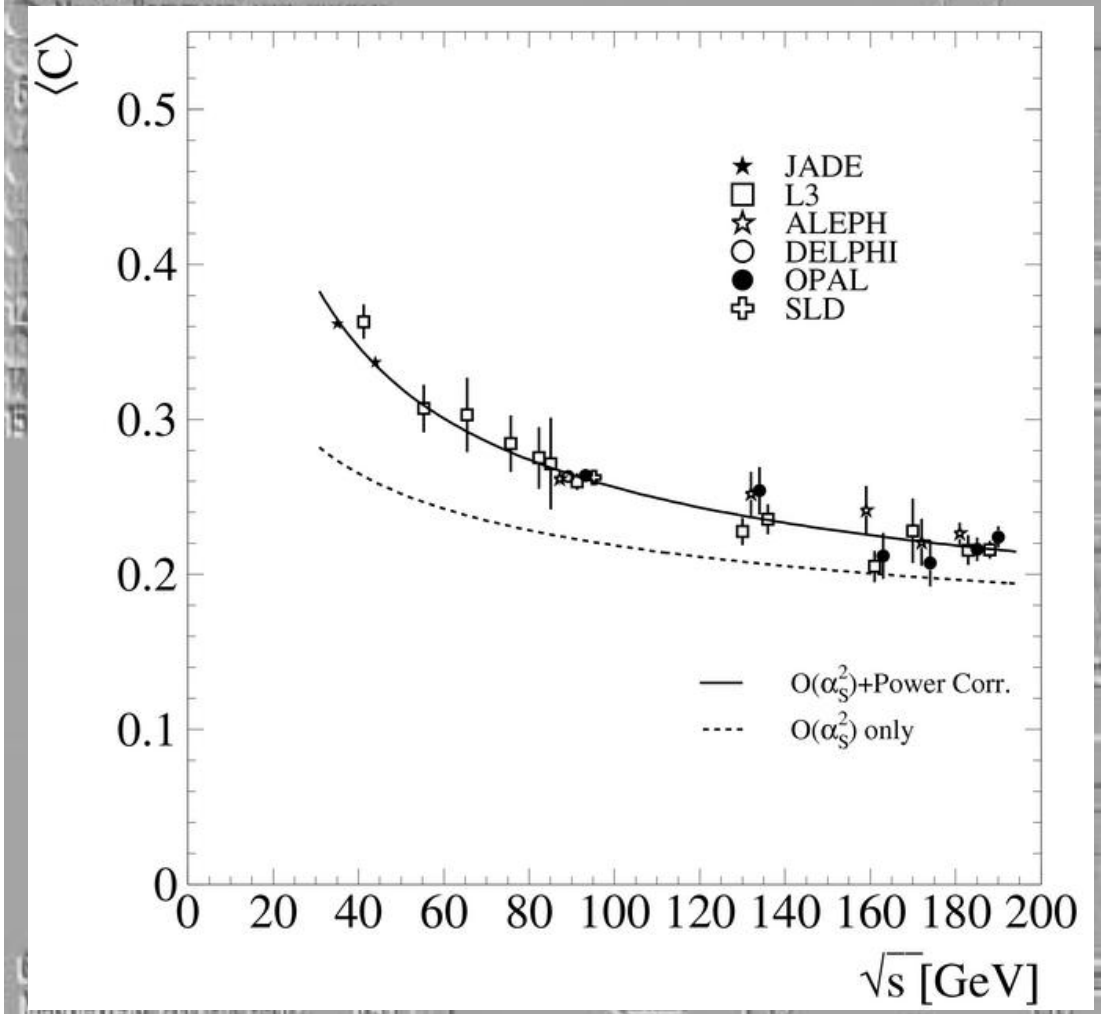
1 Why low energy e^+e^- data?



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Running strong coupling:

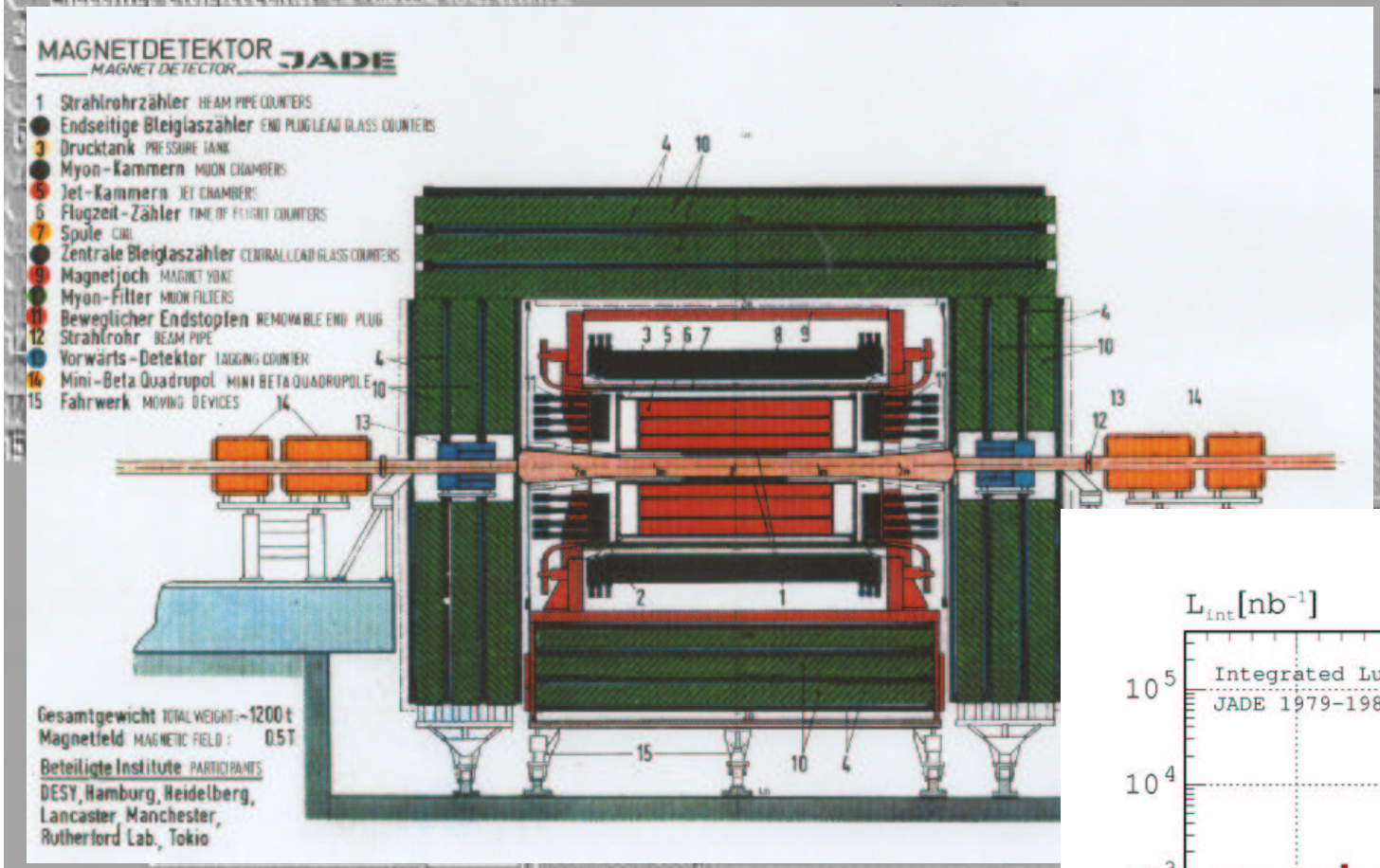
$\alpha_s(Q) = \alpha_s(\mu)/(1+2\beta_0 \ln(Q/\mu))$

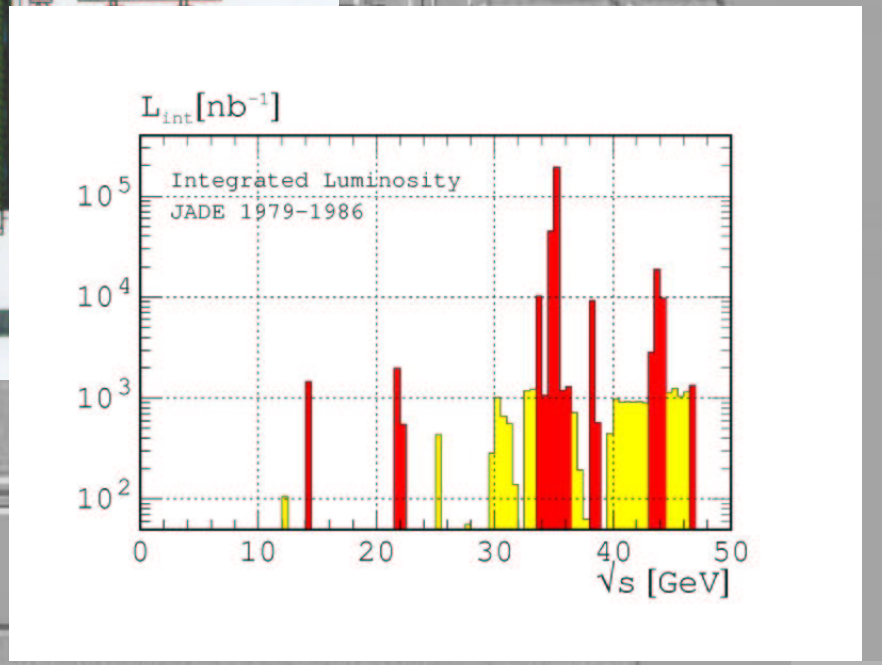
$\langle C \rangle = A_c \alpha_s(Q) + B_c \alpha_s^2(Q) + P_C/Q$

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

➔ JADE data!

1 The JADE Detector and Data

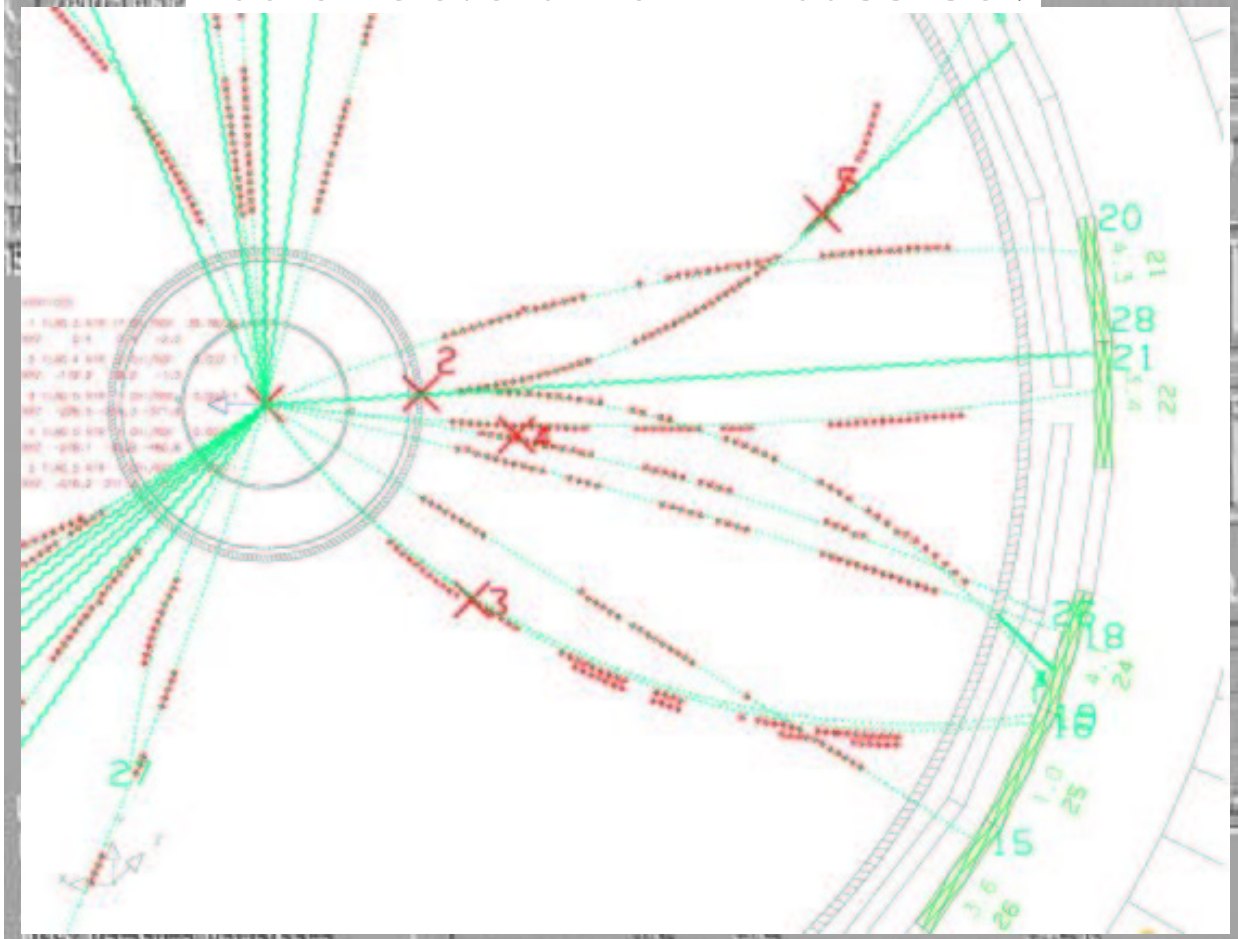




JADE @ PETRA/DESY 1979 - 1986
√s = 12 to 46,8 GeV

1 The JADE Software

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/recontruction
- ➔ compare with data or derive corrections

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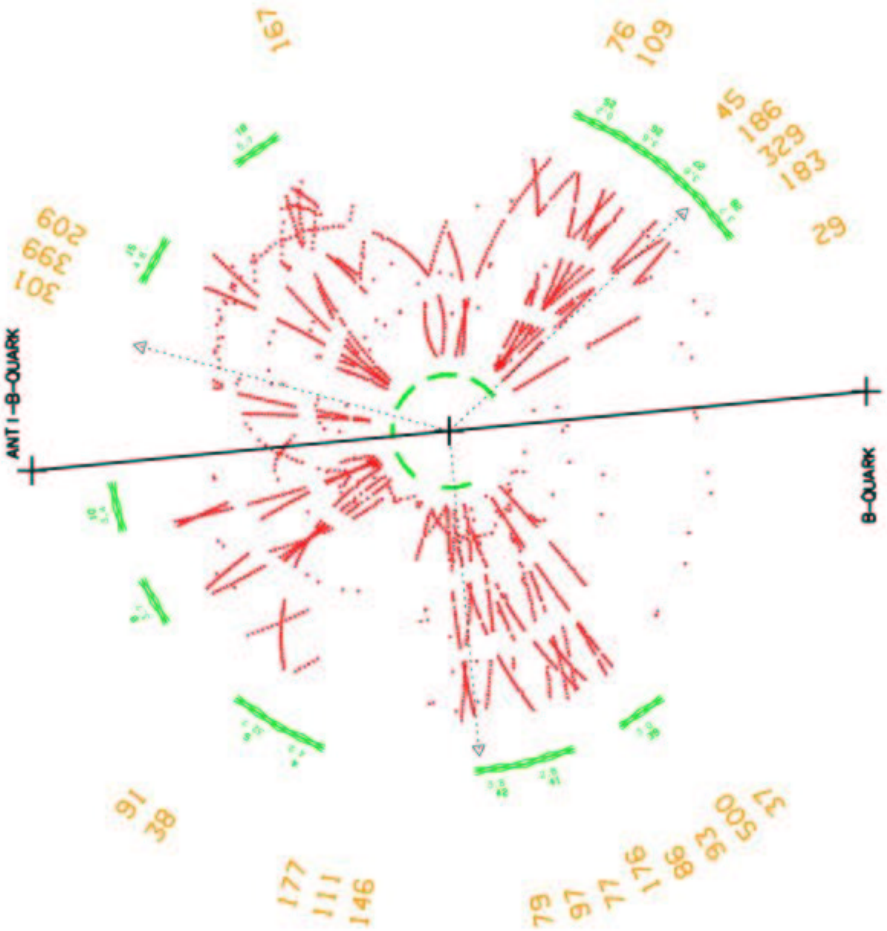
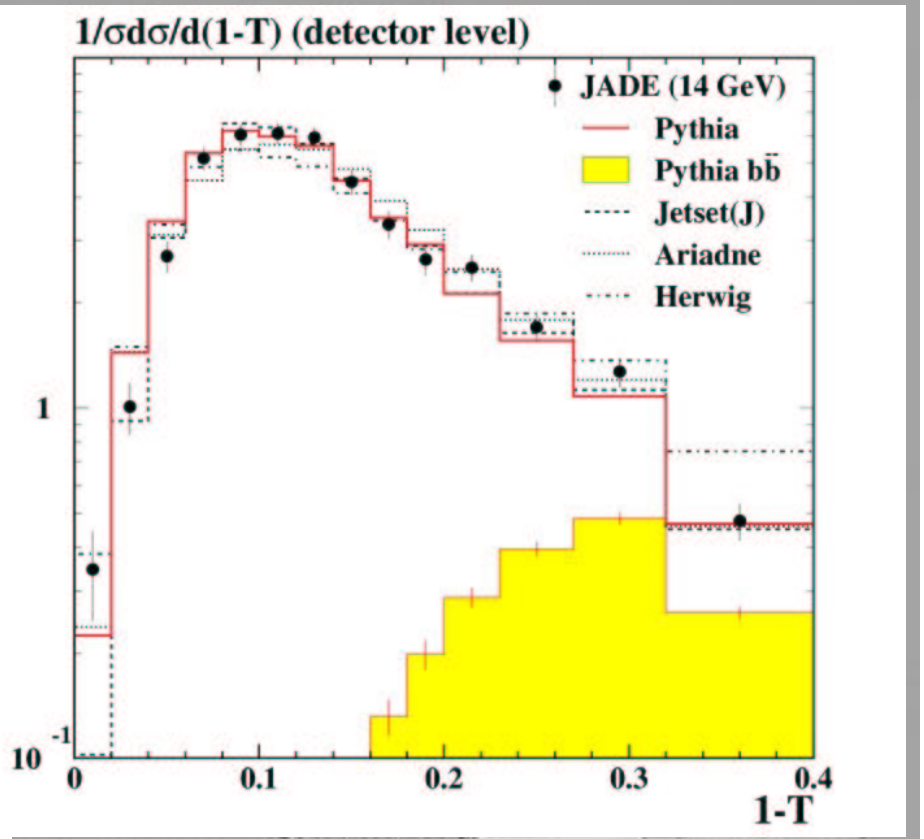
2 Background from b-production

PYTHIA b-event at 14 GeV





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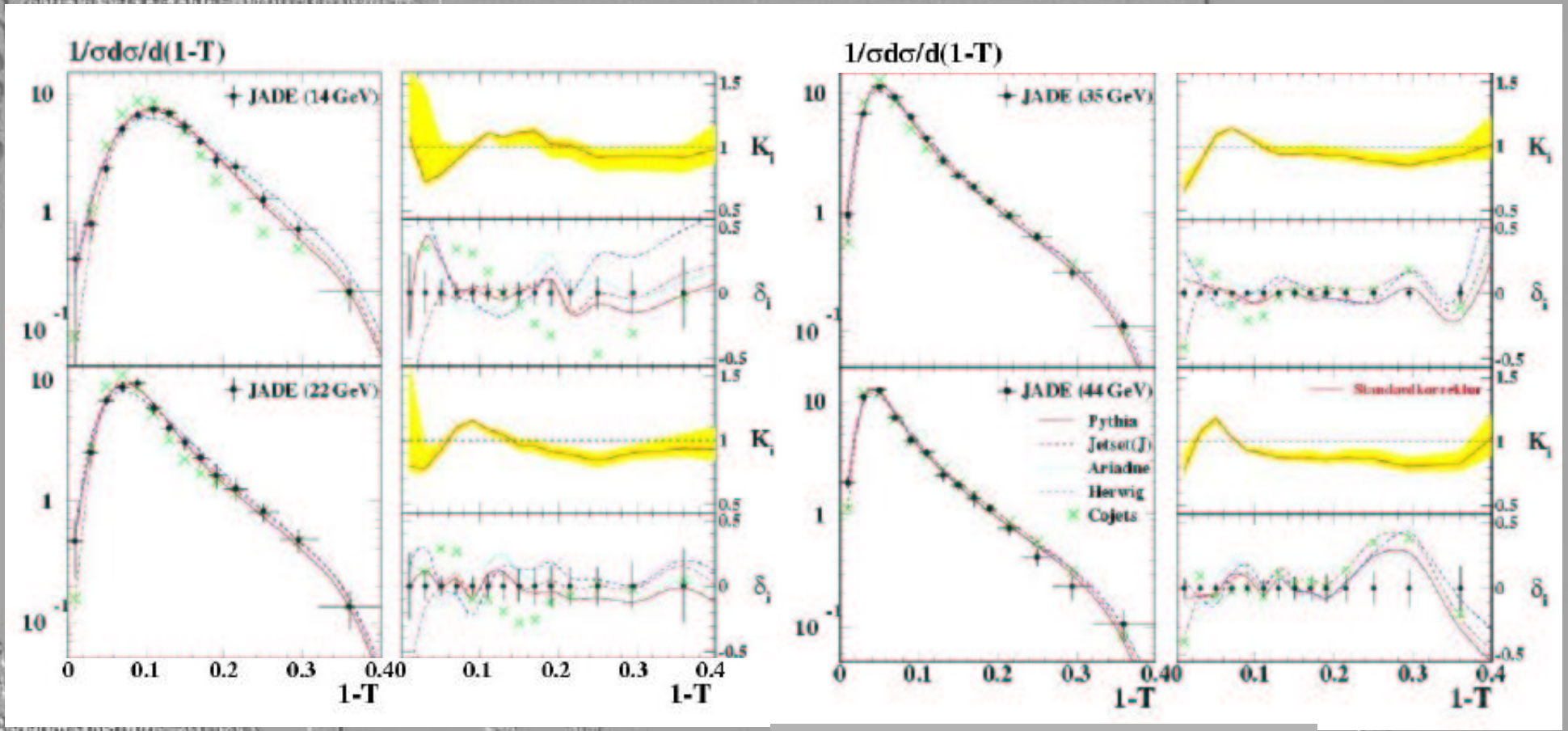
Subtract b-background (~9%), present data at udsc hadron-level

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



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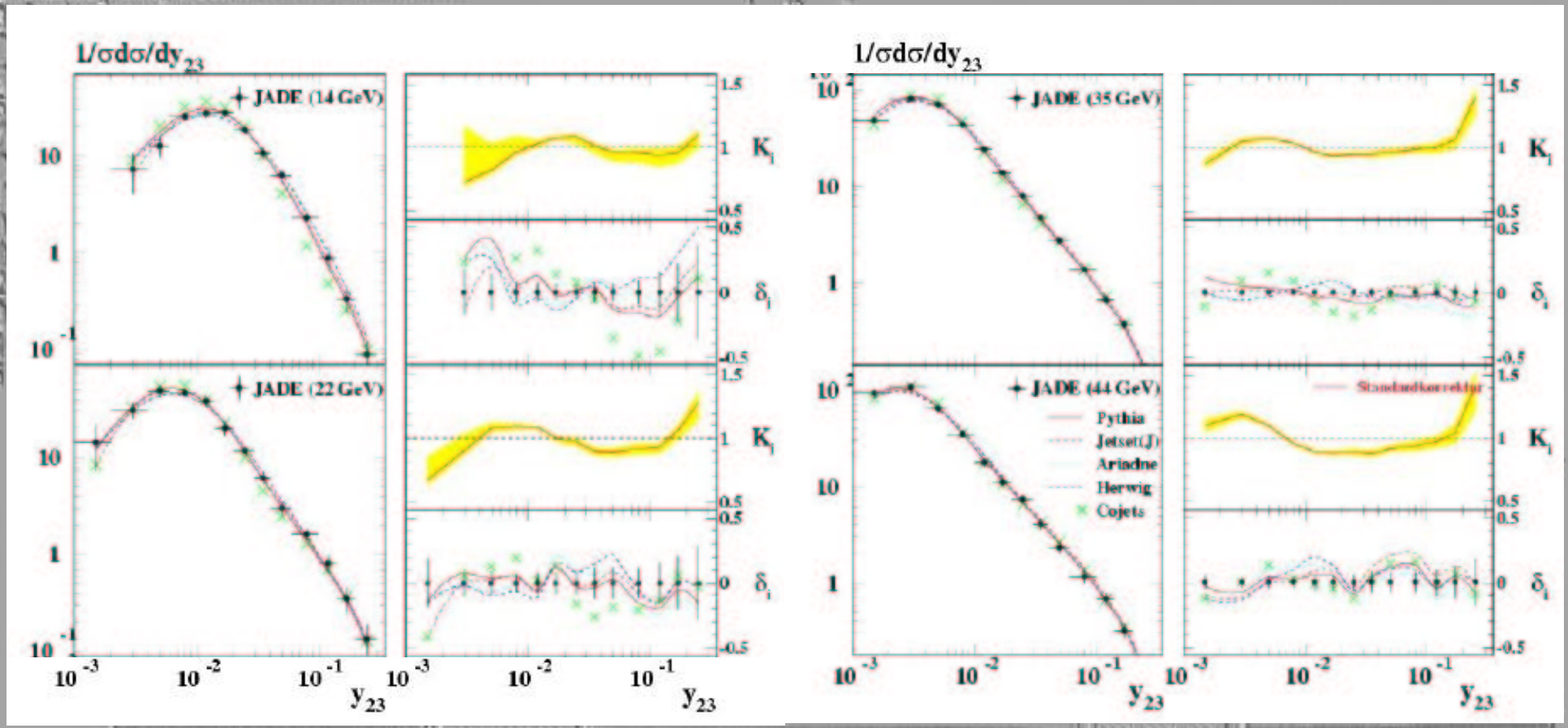
2 JADE Data vs MC: y_{23}(Durham)



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

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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 ➔ LPHD ➔ hadron spectra

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

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

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

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3 Measurements and Fits

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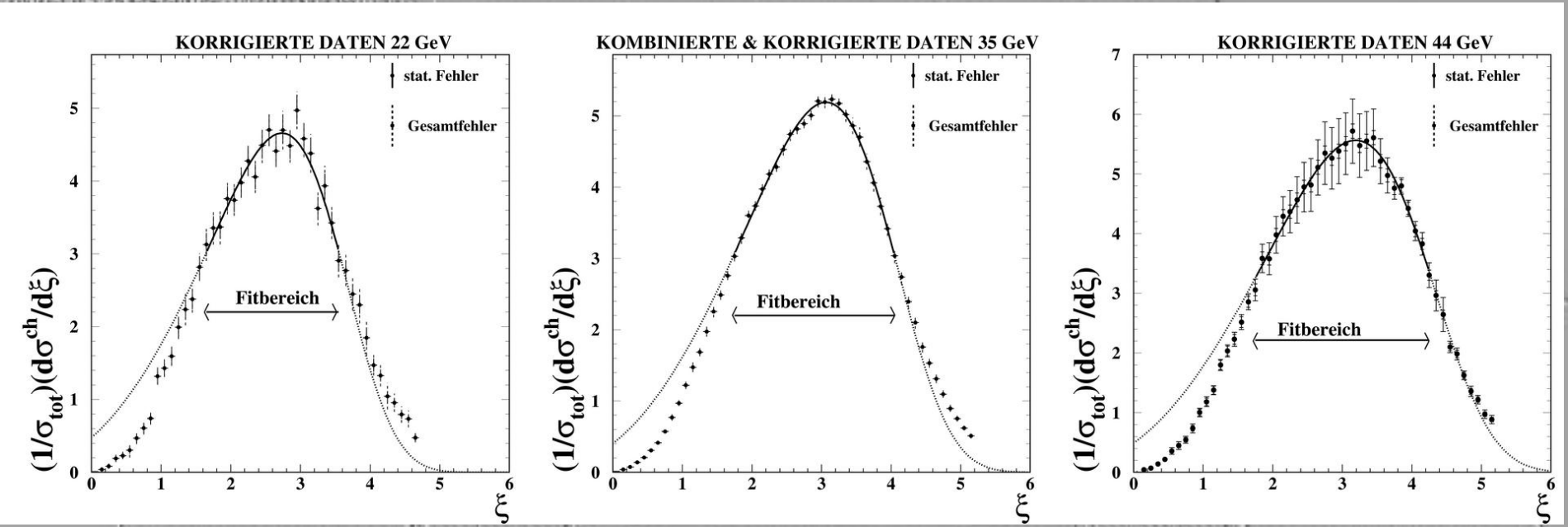
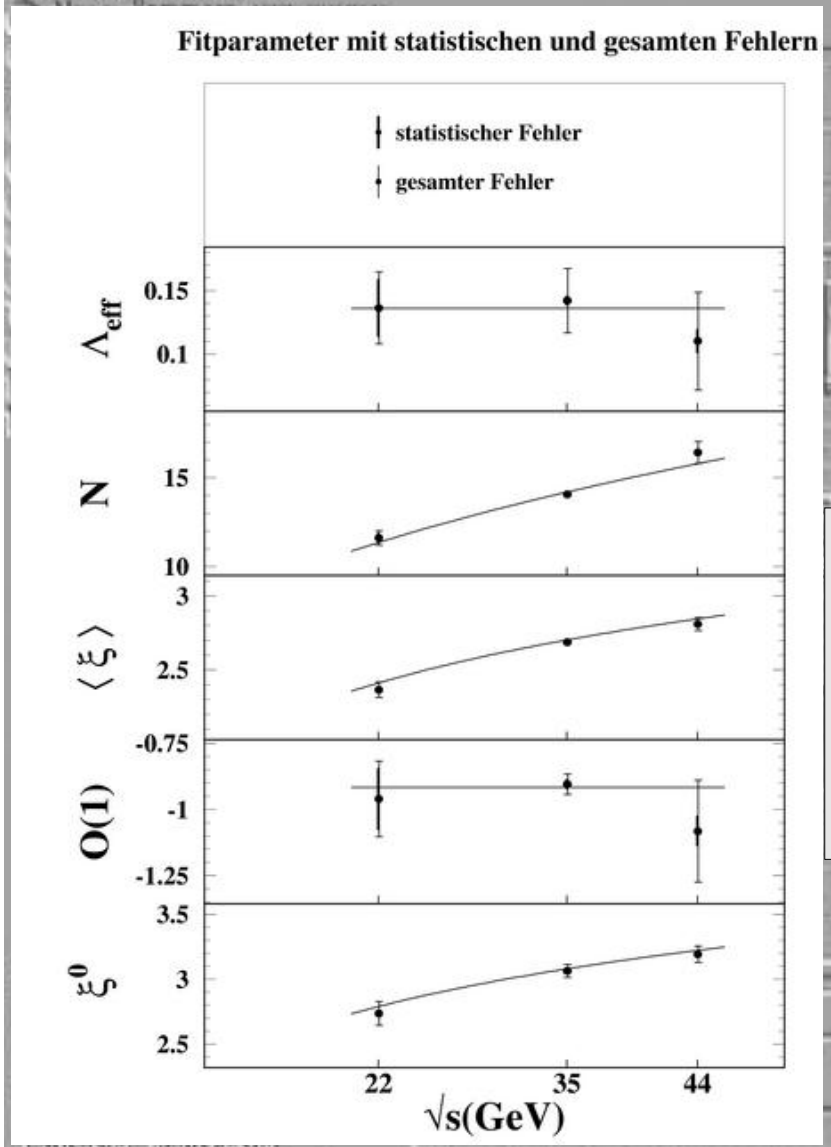


Fit MLLA (Fong/Webber): Λ_{eff}, N, and $\langle\xi\rangle$, O(1) or ξ^0

→ results for Λ_{eff}, N stable w.r.t. $\langle\xi\rangle$, O(1) or ξ^0

3 Peak Fit Results



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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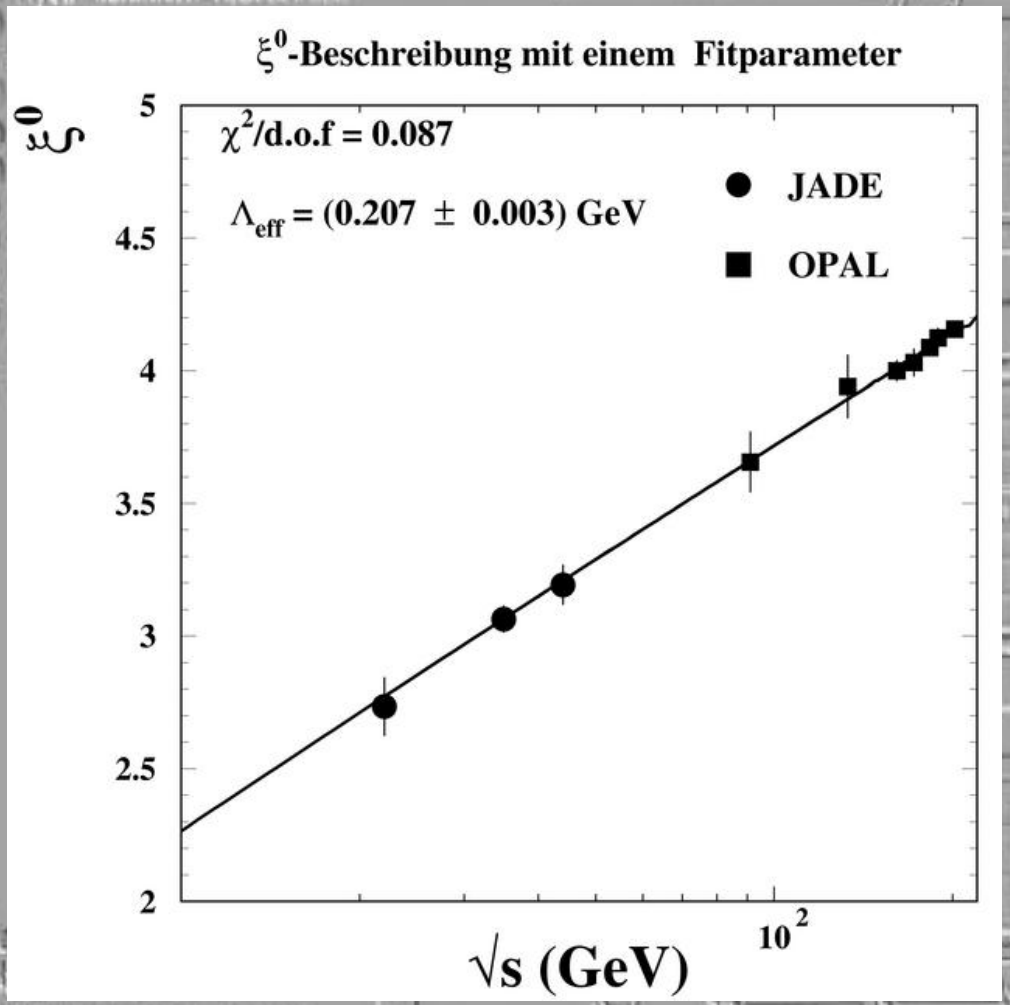
3 MLLA Peak Position Fits



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

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

Λ_{eff} = 206 ± 3 MeV

Reasonable description of data (similar result from OPAL)

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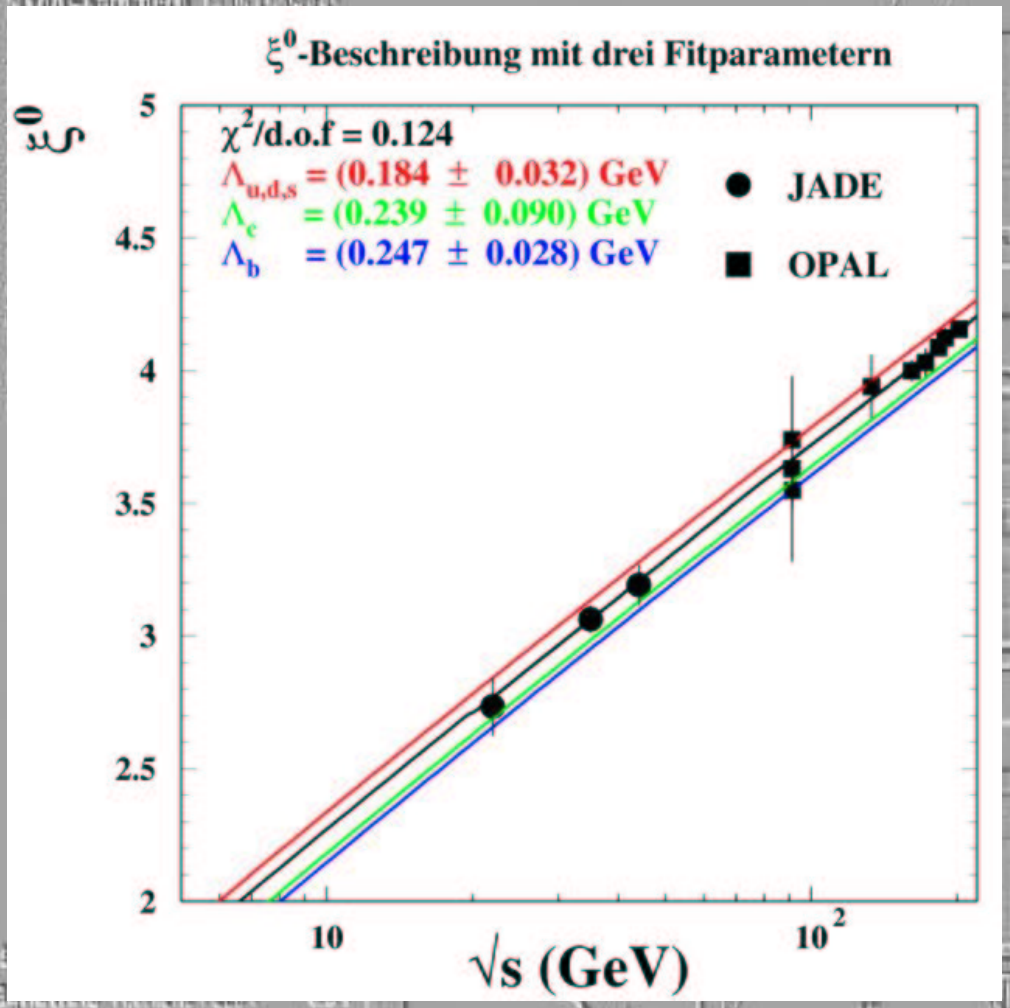
3 Flavour (Mass) Effects



$$\xi^0_{c,b} \simeq \xi^0_{uds} + 0.5 \log\left(\frac{\Lambda_{c,b}}{\Lambda_{uds}}\right)$$

Fit with Λ_b, Λ_c and Λ_{uds} with data from OPAL for ξ^0_b, ξ^0_c and ξ^0_{uds} as constraints

$$\Lambda_{uds} \quad 184 \pm 33\ MeV$$

$$\Lambda_c \quad 239 \pm 90\ MeV$$

$$\Lambda_b \quad 247 \pm 28\ MeV$$

Mass effects about 20−30%

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4 Extended Power Correction Fits

DMW model:

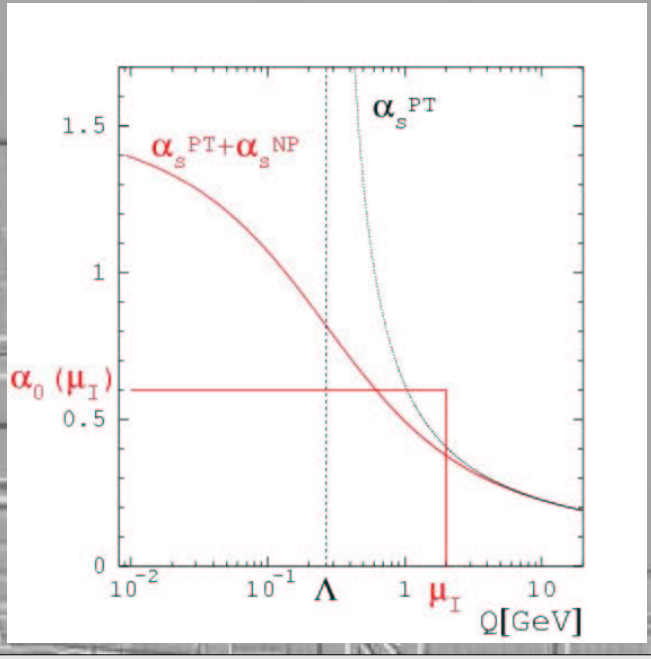
- assume integrable α_s at very low Q
- analyse renormalon ambiguities

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

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

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

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



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	$\frac{1}{2}\ln(1/B_W) + D_{B_W}(B_W, \alpha_S)$

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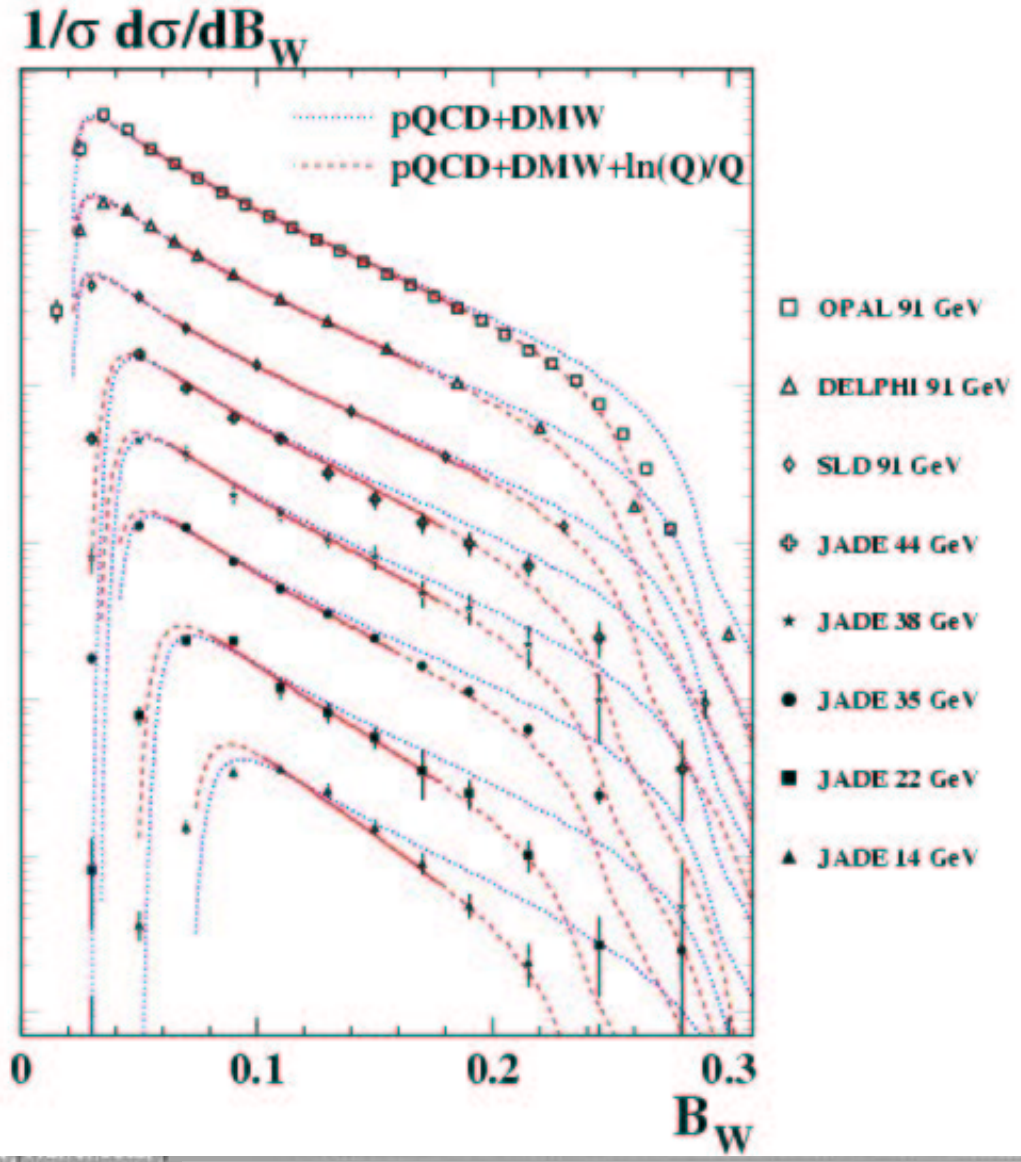
4 Extended Fits with B_W



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

χ^2(pQCD+DMW) = 65.5/24

χ^2(pQCD+DMW+A_{11}) = 22.2/23

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

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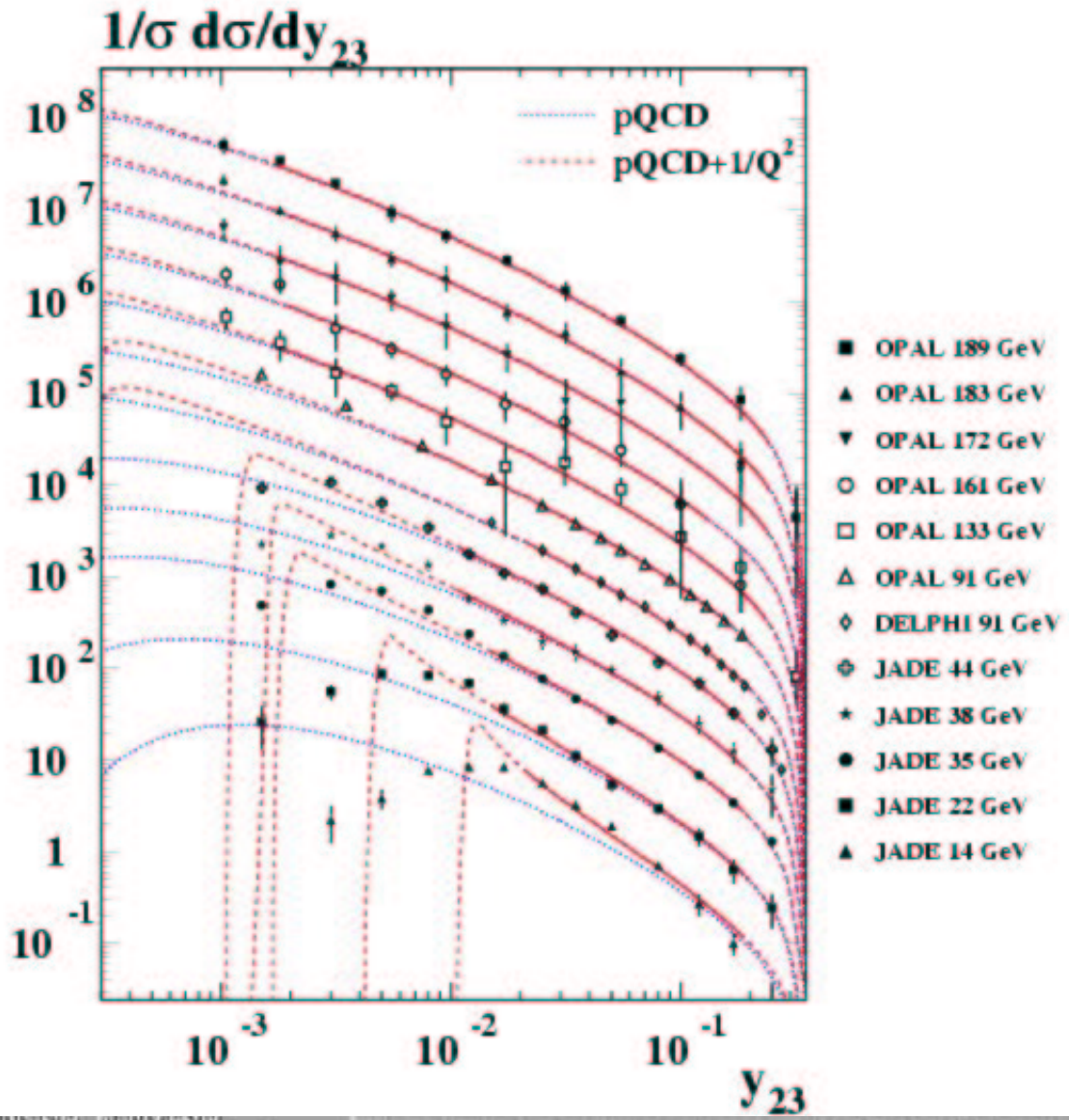
4 Extended Fits with $y_{23}(D)$



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

- extended fit ranges
- DMW prediction is $\langle y23 \rangle \sim \ln(Q)/Q^2$

χ^2(pQCD) = 151/107

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

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 ↔ 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 → additional $A_{11}\ln(Q)/Q$ contribution?
  - $y_{23}(D)$ → additional A_{20}/Q^2 contribution?