31st INTERNATIONAL CONFERENCE ON
HIGH ENERGY PHYSICS AMSTERDAM

α_s measurements from event shapes and 4 jets

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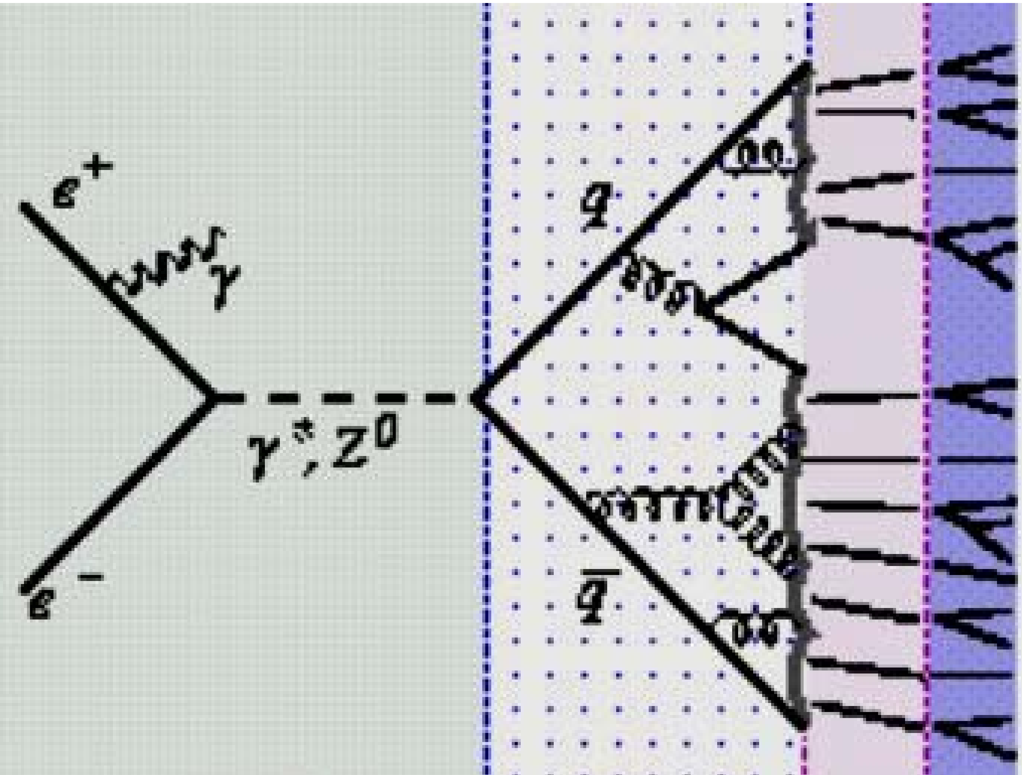
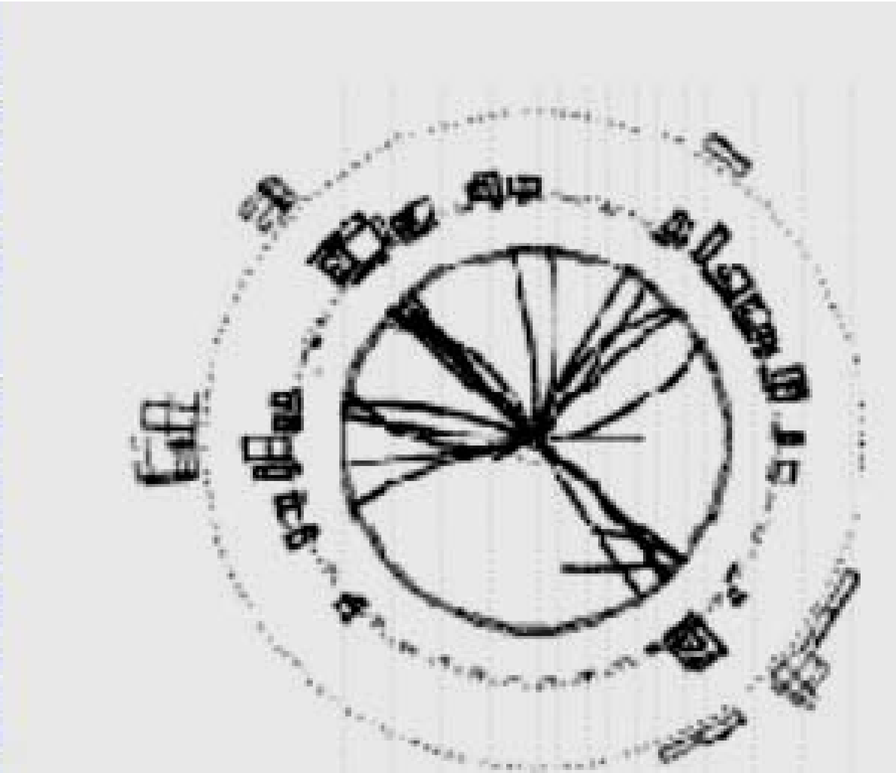
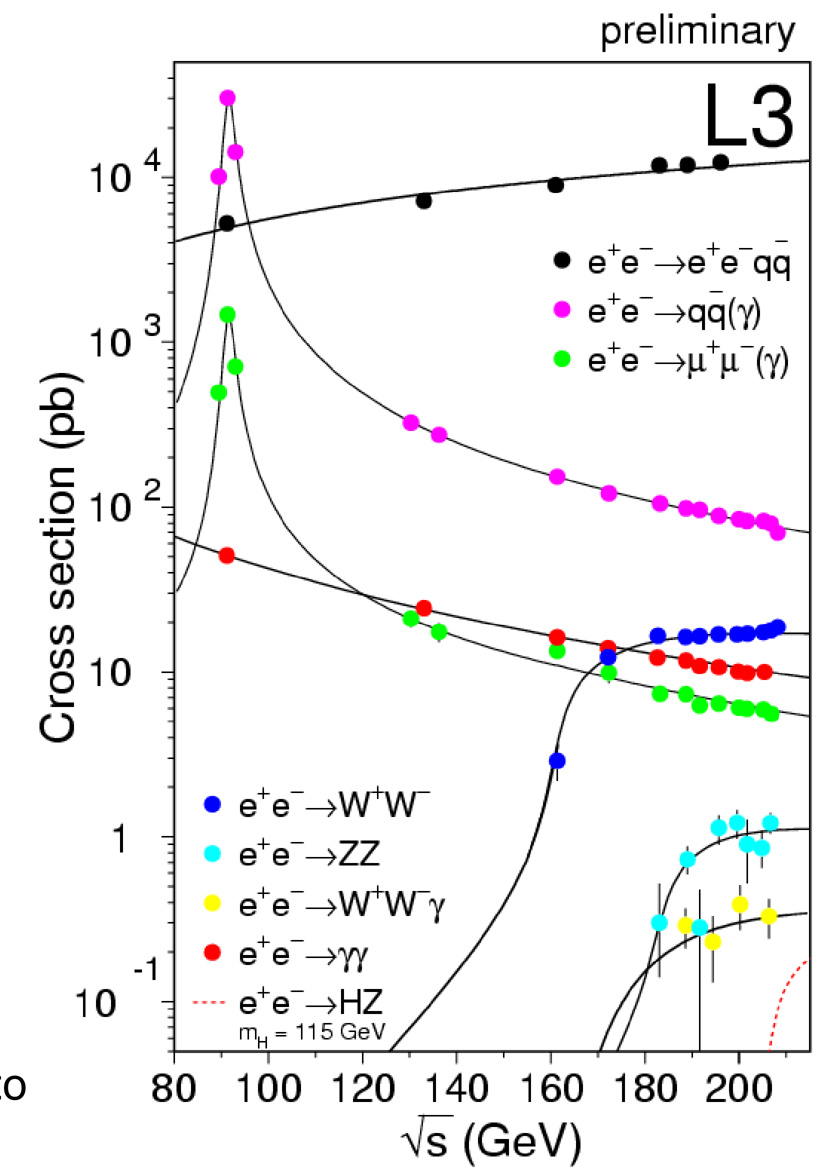




Introduction

- e^+e^- annihilation into hadrons: typical numbers (per experiment)

E_{CM} [GeV]	∫Ldt [pb^{-1}]	# evts	bckg fraction
91	100	> 10^6	few ‰
133	12	800	few ‰
161	11	300	5%
172	10	250	10%
183	60	1300	12%
189	170	3500	13%
200	200	3500	14%
206	210	3500	15%

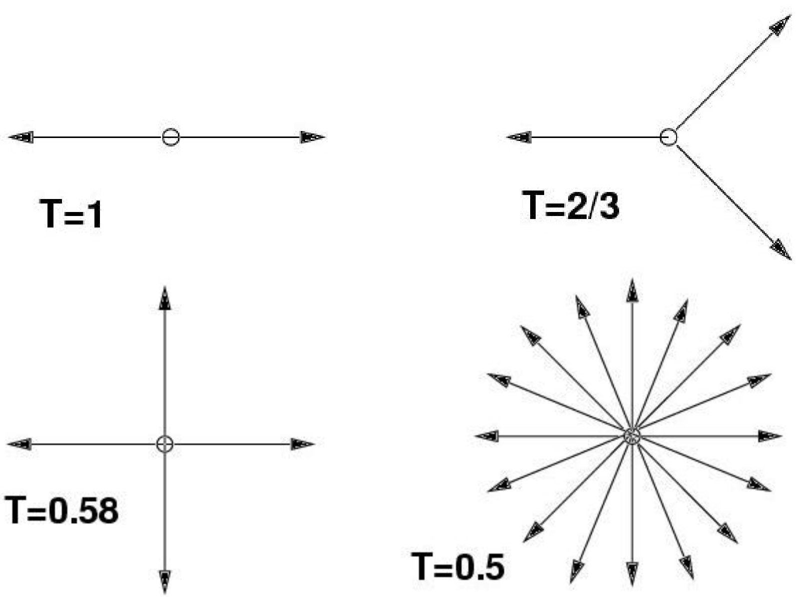


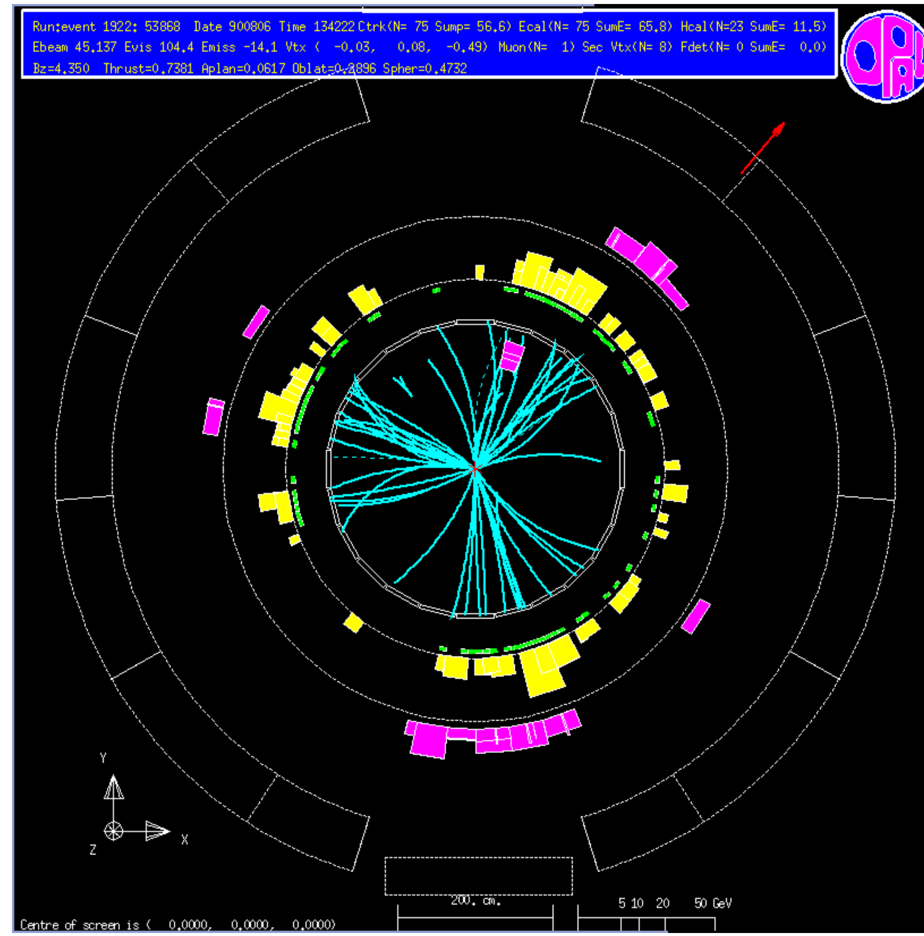
- Selection issues :
  - ISR, 4-fermion background (WW,ZZ)
  - Many energy points, some combined into single point (eg. 204-209 ⇒ 206 GeV)

Event Shapes

- Example : Thrust

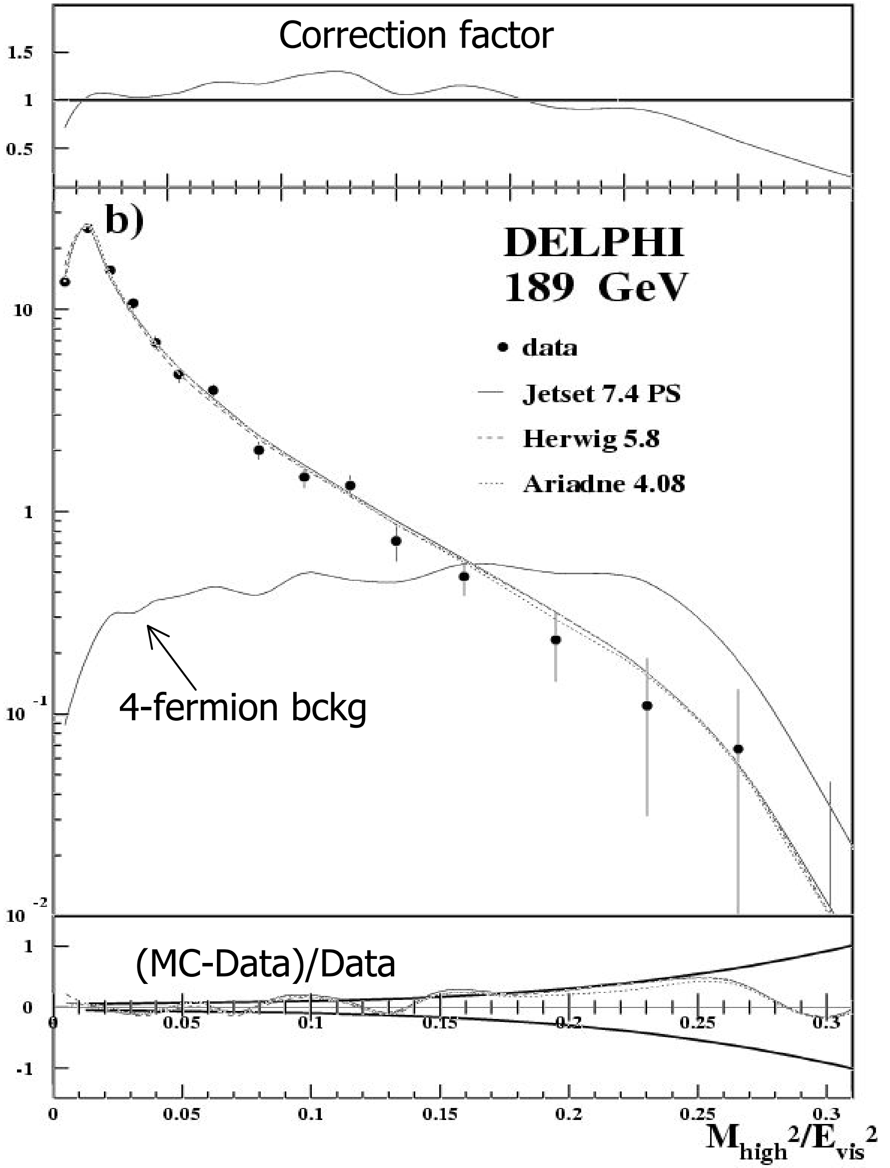
$$T = \max_{\vec{n}_T} \left(\frac{\sum_i |\vec{p}_i \cdot \vec{n}_T|}{\sum_i |\vec{p}_i|} \right)$$





- **Further variables** : heavy jet mass M_H, C-parameter C, total and wide jet broadenings B_T and B_W, diff. 2-jet rate (Durham, y_3)

Measurements



- Typically measured from charged and neutral particles
- Corrected for acceptance, resolution, residual ISR contamination
- 4-fermion background subtracted
- in general good description of data by MCs

α_s Fits

- NLO $O(\alpha_s^2)$ pQCD prediction for event shape variables

$$\frac{1}{\sigma}\frac{d\sigma}{dy} = \alpha_S(\mu^2)A(y) + \alpha_S^2(\mu^2)B(y,\mu^2)$$

y event-shape variable
μ renormalisation scale

- NLLA (resummed) prediction

$$R(y) = \mathcal{F}(\alpha_S)\, e^{Lg_1(\alpha_S L)+g_2(\alpha_S L)}$$

leading (g_1) and sub-leading logs (g_2) to all orders in α_S
$L = \log\frac{1}{y},\ R(y) = \int \frac{1}{\sigma}\frac{d\sigma}{dy}$

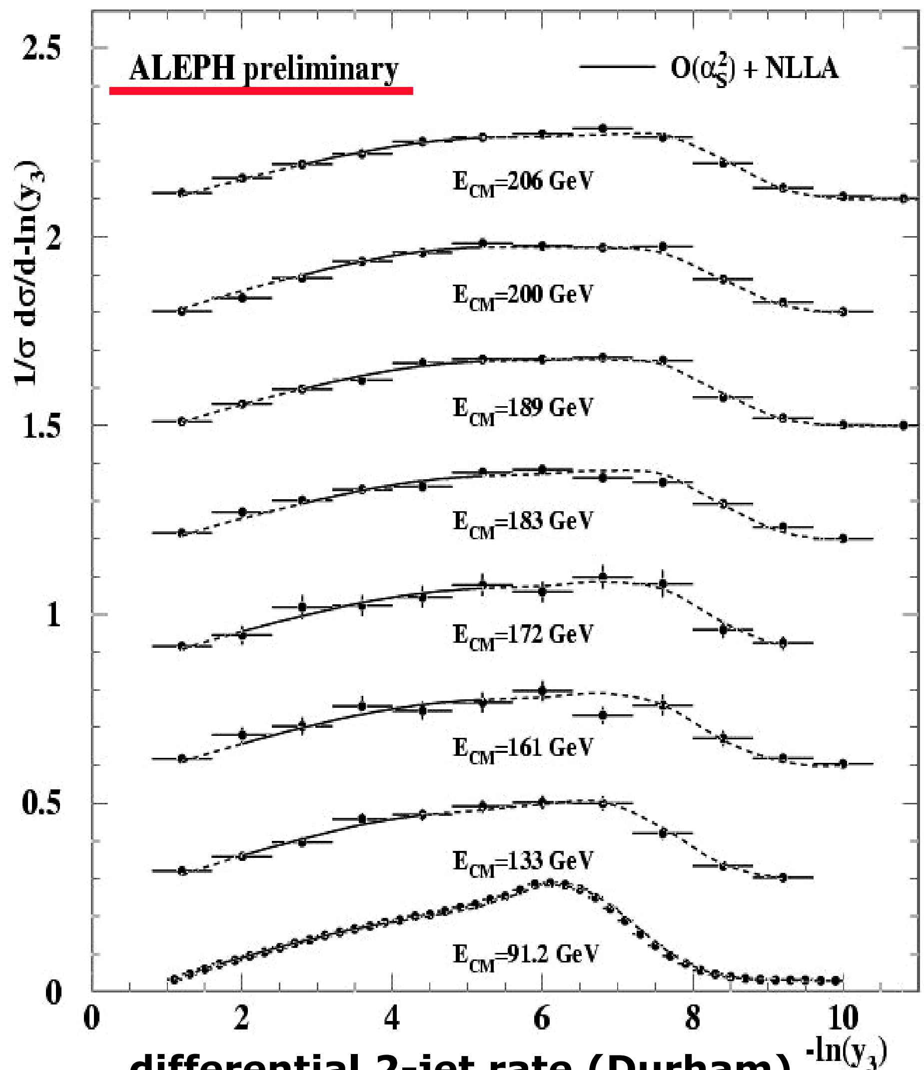
- Two matching schemes to combine $O(\alpha_s^2)$ and resummed predictions, LogR and R.
- LEPQCD WG adopts modified matching schemes, which ensure physical behaviour at the phase space boundary y_{max}

$$L \to \tilde{L} = \frac{1}{p}\ln\left(\left(\frac{1}{y}\right)^p - \left(\frac{1}{y_{max}}\right)^p + 1\right)$$

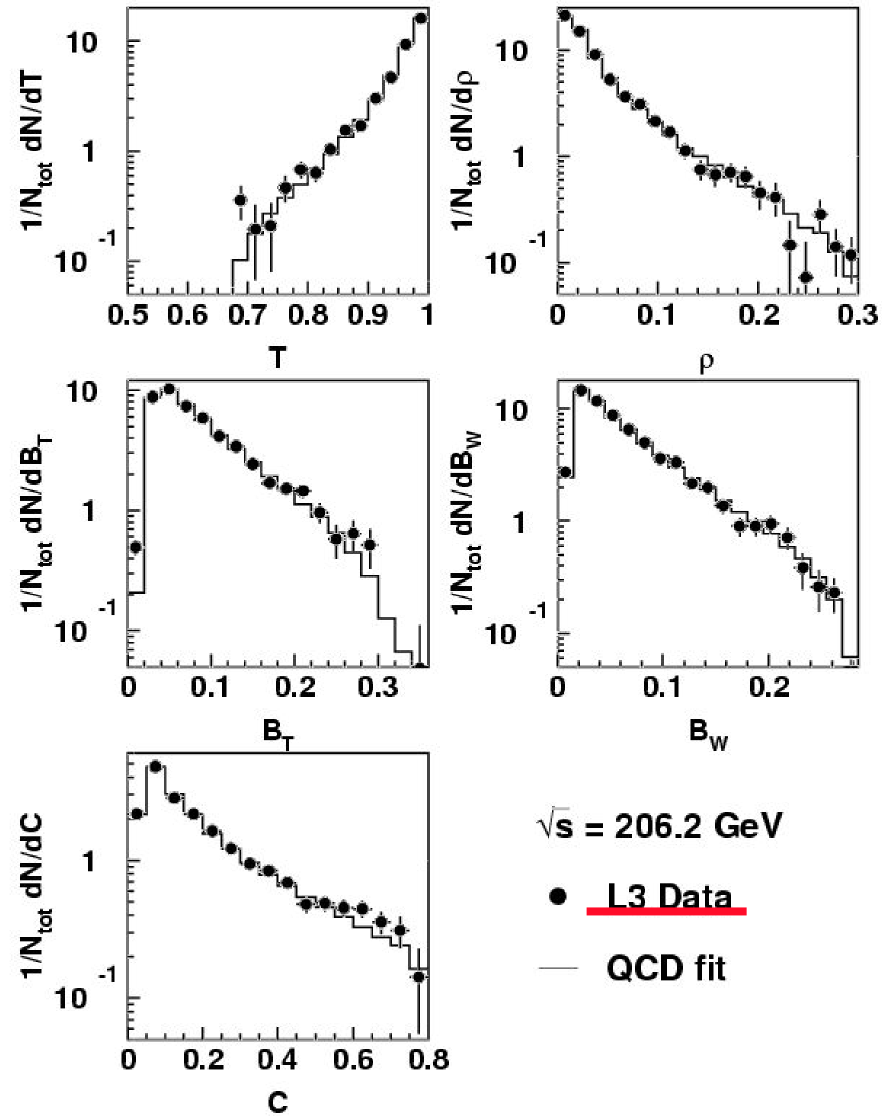
p=1 modified LogR
p=2 second degree modification

- pQCD predictions corrected for hadronization using MC (PY, HW, AR)

Fit Results



differential 2-jet rate (Durham)
improved theo. pred. since recently



Systematic Uncertainties

- Experimental Uncertainties
  - track reconstruction, event selection, detector corrections : via cut variations or different MC generators
  - background subtraction (LEP2)
  - ISR corrections (LEP2)
  - typically around 1%
- Hadronization Uncertainties
  - difference between various models for hadronization : Pythia (String frag.), Herwig (Cluster frag.), Ariadne (Dipole model + String frag.)
  - typically around 0.7 - 1.5 %
- Theoretical Uncertainties (pQCD)
  - LEPQCD WG has come up with a new prescription :

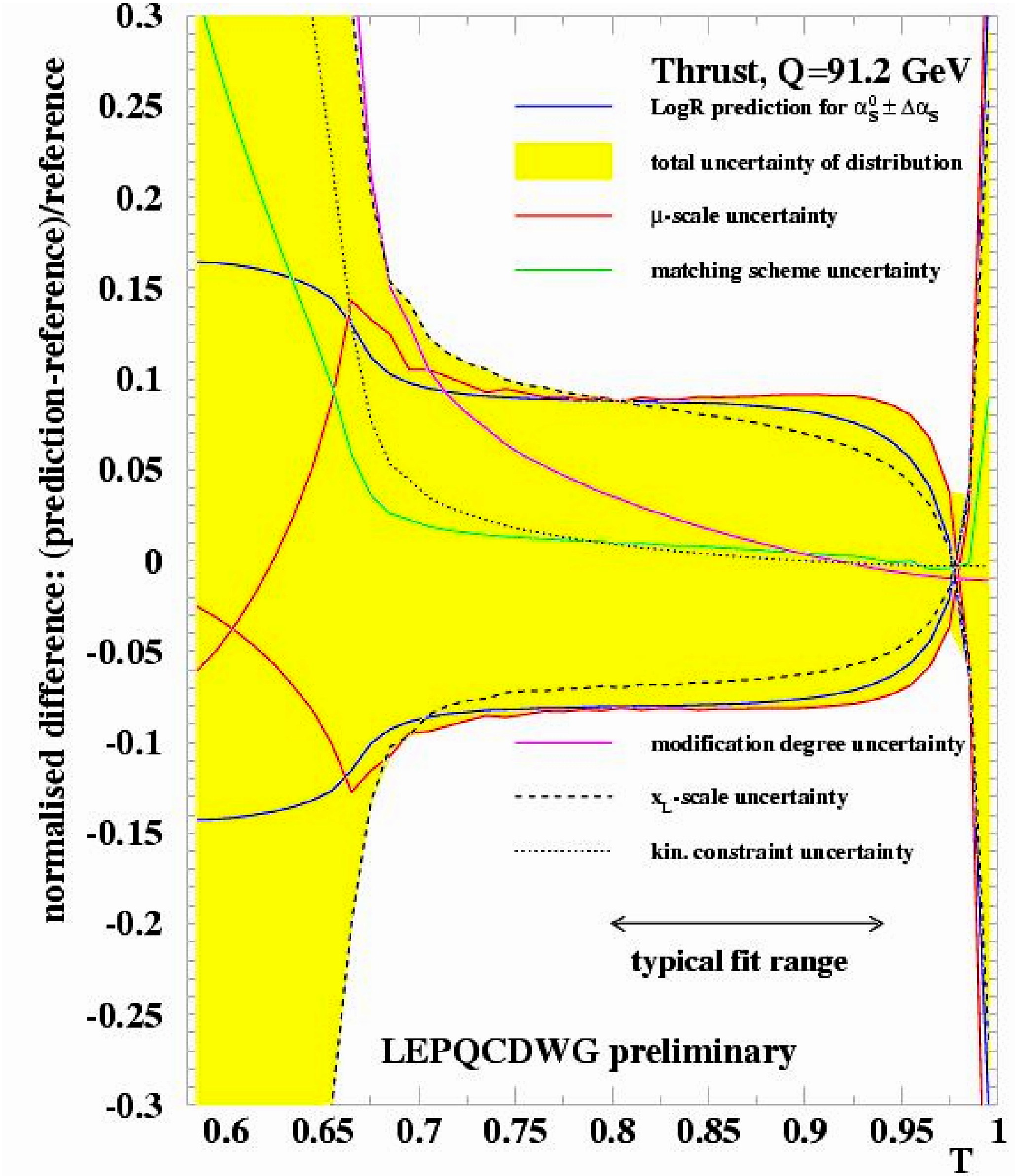
    Uncertainty band method

Theoretical Uncertainty

- Uncertainty band obtained (for fixed α_s) via variations:
  - renormalization scale
  - rescaling factor $L'=1/\ln(x_L\ y)$
  - kinematic constraint y_{max}
  - modification degree

- for fixed reference prediction (LogR) find α_s variation which covers this band (within the fit range)

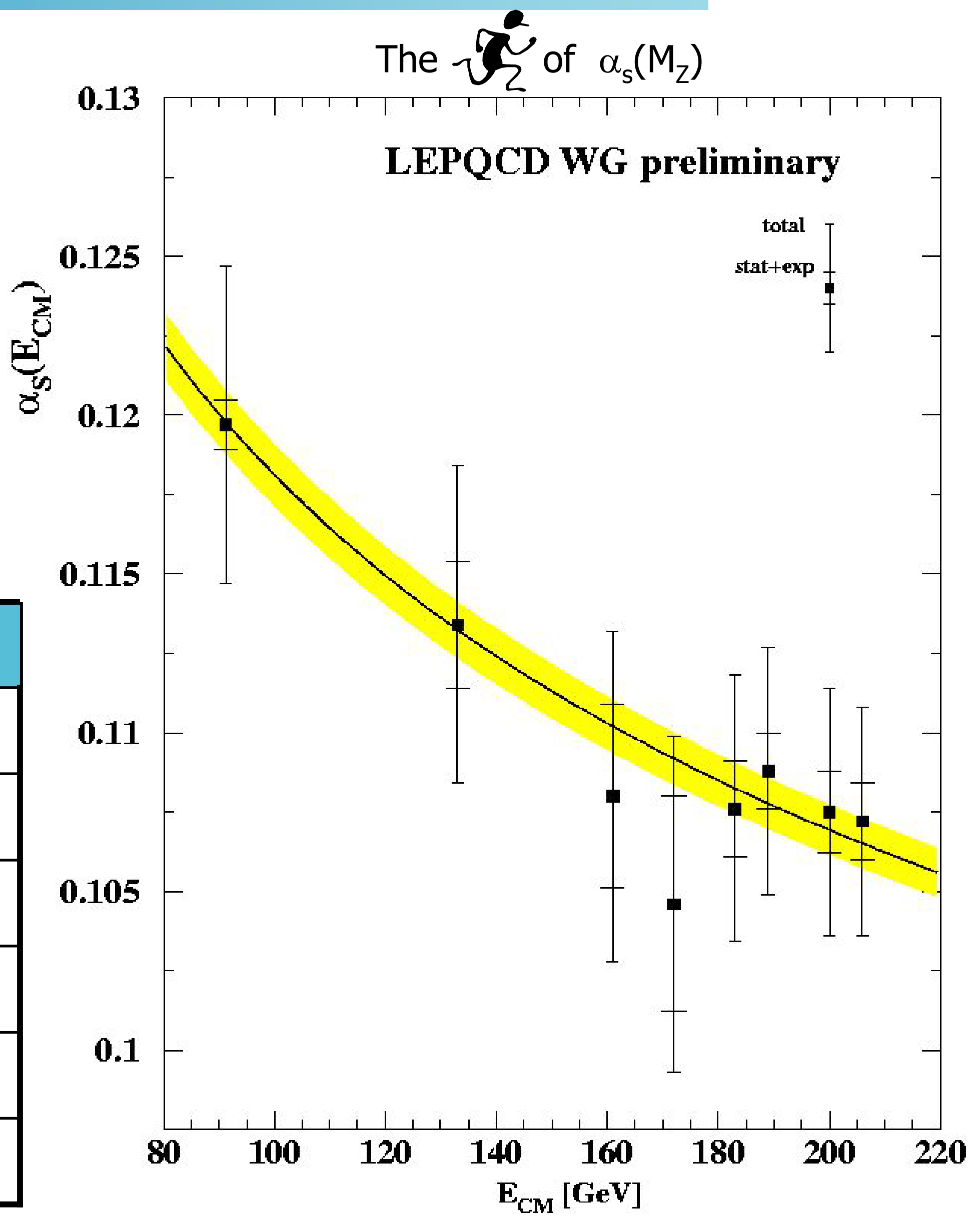
- typically 3.5 - 5 %



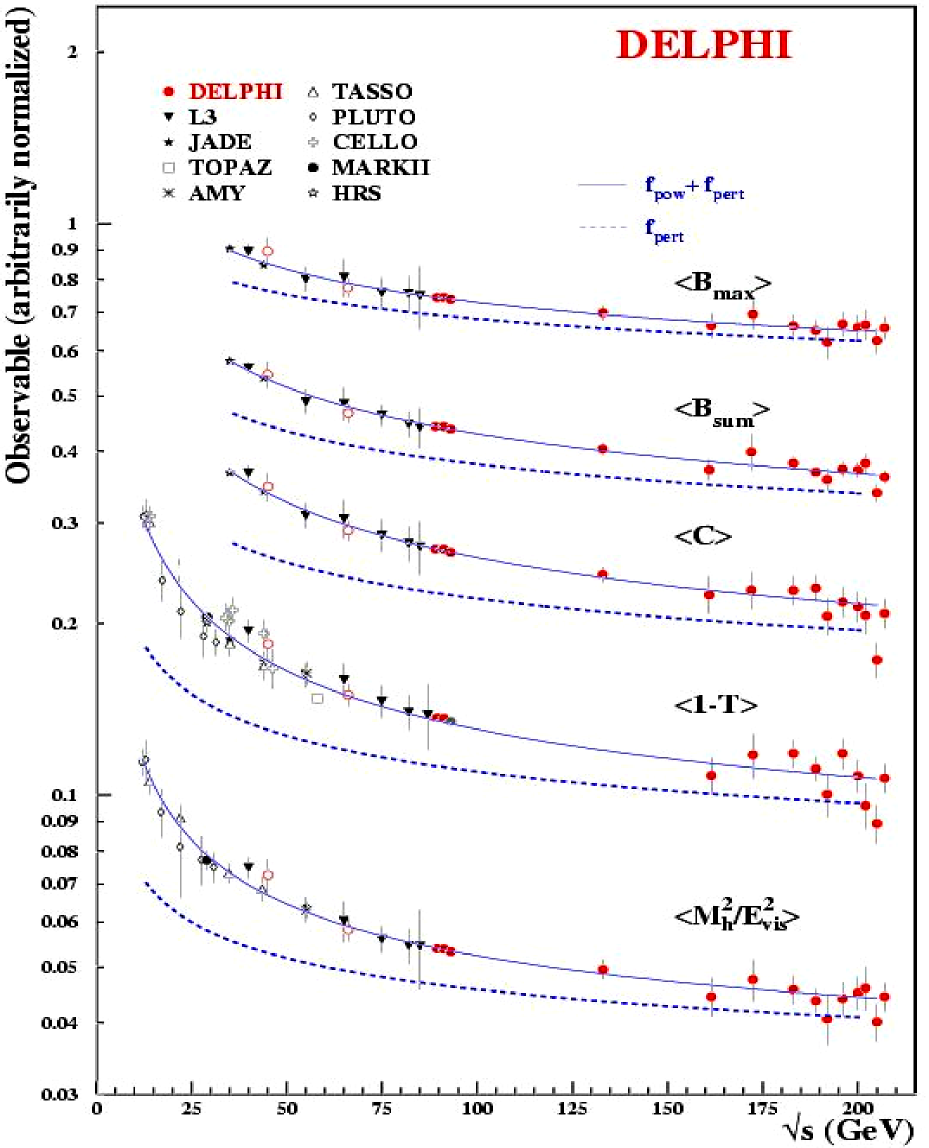
Combined Result

- LEPQCD WG combination:
  - different variables
  - different energies
  - different experiments
  - results evolved to M_Z
  - includes also L3 results down to E_{CM}=40 GeV (ISR)

prelim	all LEP	LEP I	LEP II
$\alpha_s(M_Z)$	0.1198	0.1197	0.1197
Δ stat	0.0002	0.0002	0.0006
Δ exp	0.0009	0.0008	0.0010
Δ had	0.0008	0.0010	0.0007
Δ theo	0.0045	0.0048	0.0045
Δ tot	0.0047	0.0050	0.0047



Power Law Corrections



- Delphi has updated their study of power law corrections :

$$\langle y \rangle = \alpha_s(\mu^2)A + \alpha_s^2(\mu^2)B + C\frac{\alpha_0(\mu_I^2)}{Q}$$

$\alpha_s(M_Z)$ = 0.1184 ±0.0004 (stat)
± 0.0008 (exp)
± 0.0008 (had)
± 0.0031 (scale)

= 0.1184 ± 0.0033

4-jet rate

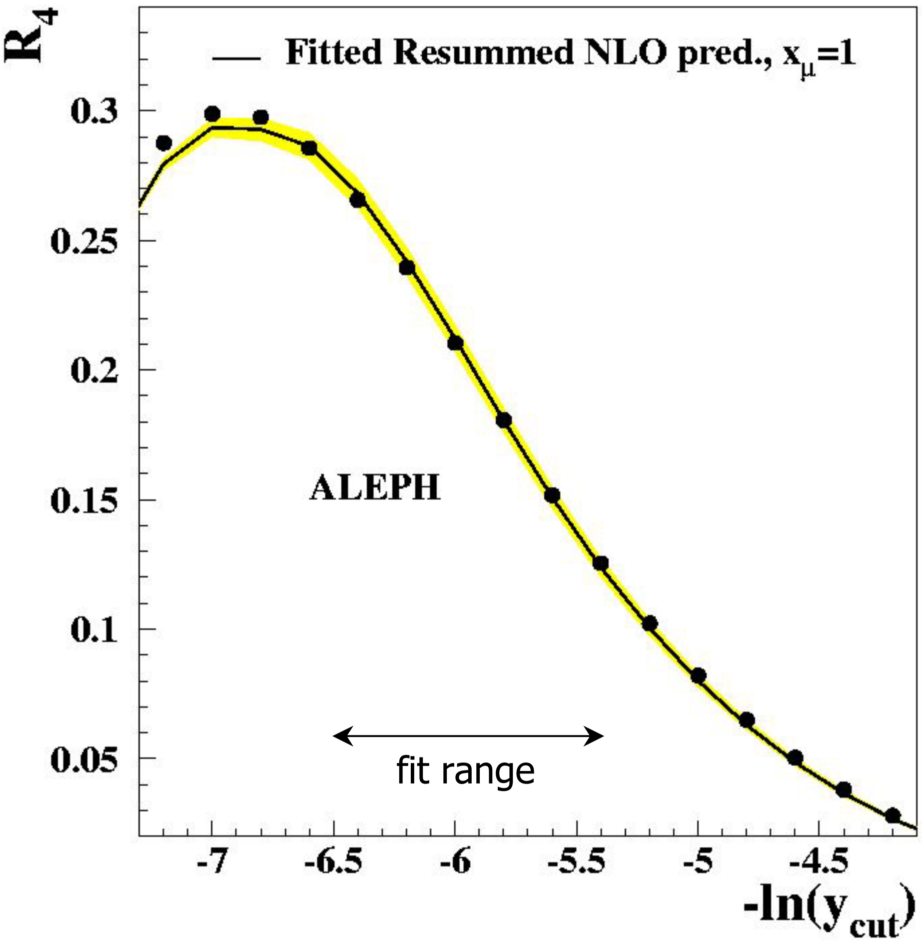
- predictions (for Durham) know at NLO + resummation

$$R_4(y_{cut}) = \alpha_s^2(\mu^2)B(y_{cut}) + \alpha_s^3(\mu^2)C(y_{cut}) + f(\alpha_s^n \ln^m y_{cut})$$

- note : $\dfrac{\Delta\alpha_s}{\alpha_s} = \dfrac{1}{2}\dfrac{\Delta\sigma}{\sigma}$

- ALEPH (x_μ=1):

$\alpha_s(M_z)$ = 0.1170 ± 0.0001 (stat)
± 0.0009 (exp)
± 0.0003 (had)
± 0.0008 (scale)
= 0.1170 ± 0.0013



- x_μ = 0.729 : $\alpha_s(M_z)$ = 0.1175 ± 0.0013

- similar result shown by DELPHI in a previous conf.

Conclusions

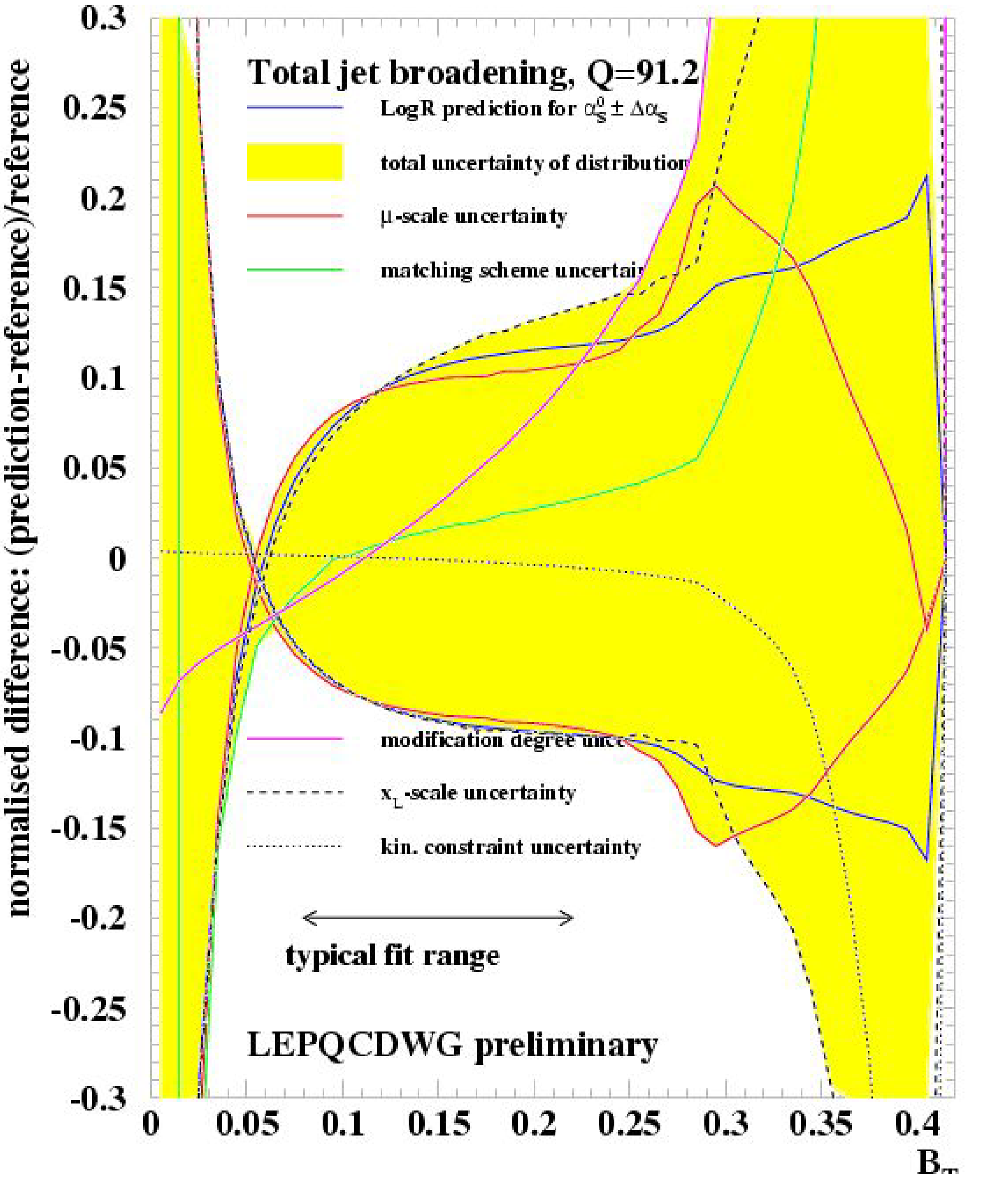
- α_s measured from event-shape variables at LEPI and LEPII, new LEP average
- new method for estimating theoretical uncertainties
- very precise measurements also obtained using mean values together with power law corrections, as well as the 4-jet rate

Theoretical Uncertainty

- Uncertainty band obtained (for fixed α_s) via variations:
  - renormalization scale
  - rescaling factor $L' = 1/\ln(x_L\, y)$
  - kinematic constraint
  - modification degree

- for fixed reference prediction (LogR) find α_s variation which covers this band (within the fit range)

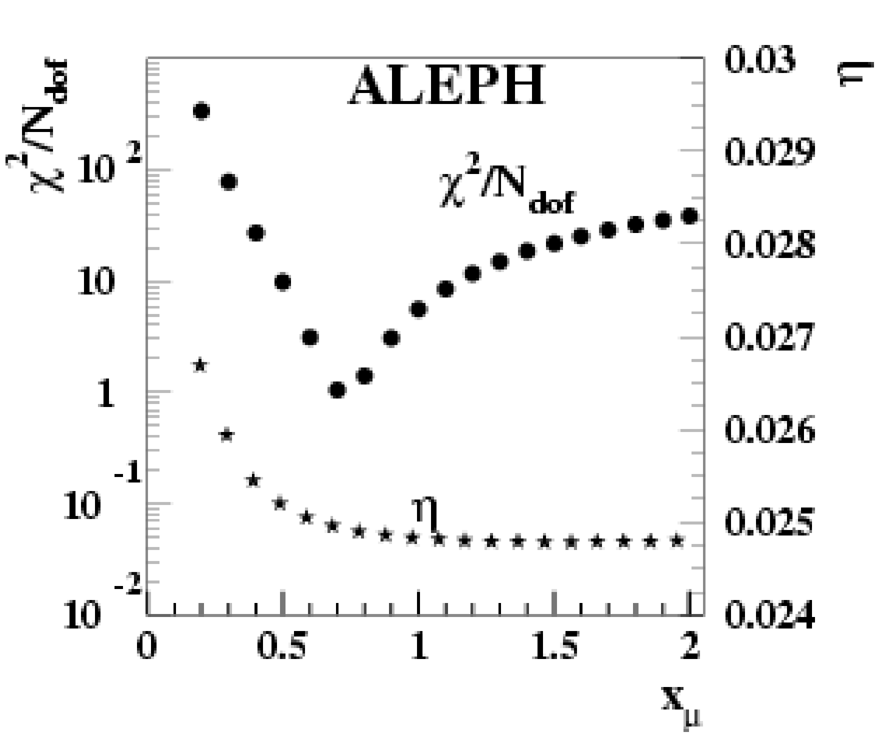
- typically 3.5 - 5 %

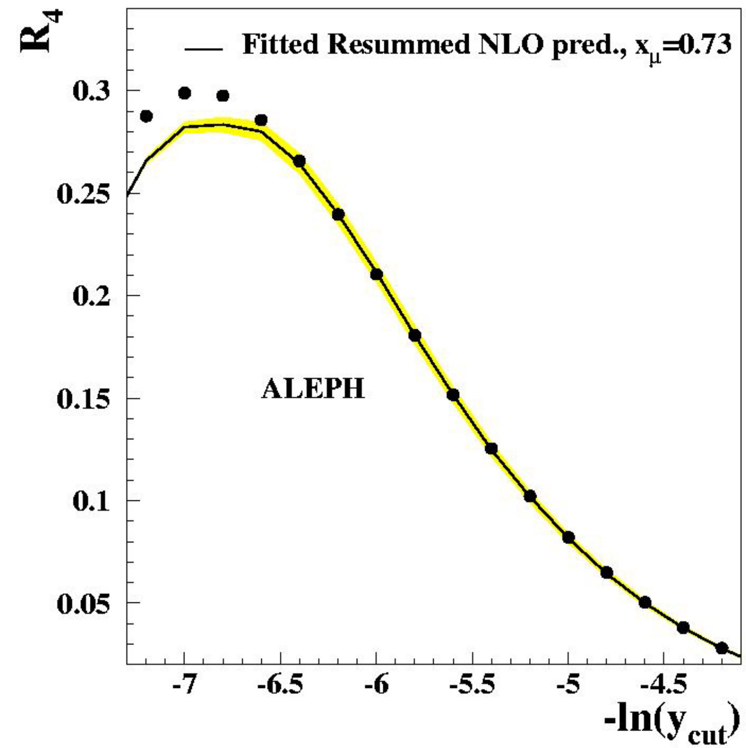


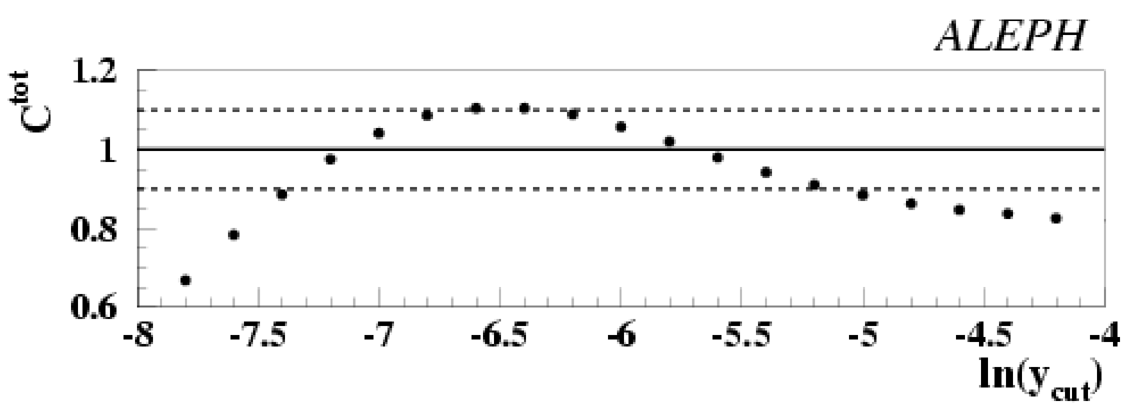
LEP results

Q	$\alpha_s(Q)$	stat	exp	hadr	theo
41.4	0.1415	0.0024	0.0027	0.0018	0.0077
55.3	0.1260	0.0023	0.0049	0.0045	0.0067
65.4	0.1332	0.0015	0.0031	0.0041	0.0061
75.7	0.1190	0.0012	0.0051	0.0045	0.0056
82.3	0.1174	0.0013	0.0037	0.0051	0.0055
85.1	0.1140	0.0018	0.0041	0.0051	0.0056
91.2	0.1197	0.0002	0.0008	0.0010	0.0048
133.0	0.1134	0.0016	0.0012	0.0010	0.0045
161.0	0.1080	0.0025	0.0014	0.0003	0.0043
172.0	0.1046	0.0029	0.0017	0.0006	0.0040
183.0	0.1076	0.0013	0.0008	0.0007	0.0038
189.0	0.1089	0.0008	0.0009	0.0006	0.0037
200.0	0.1074	0.0009	0.0010	0.0006	0.0036
206.0	0.1073	0.0009	0.0008	0.0005	0.0034

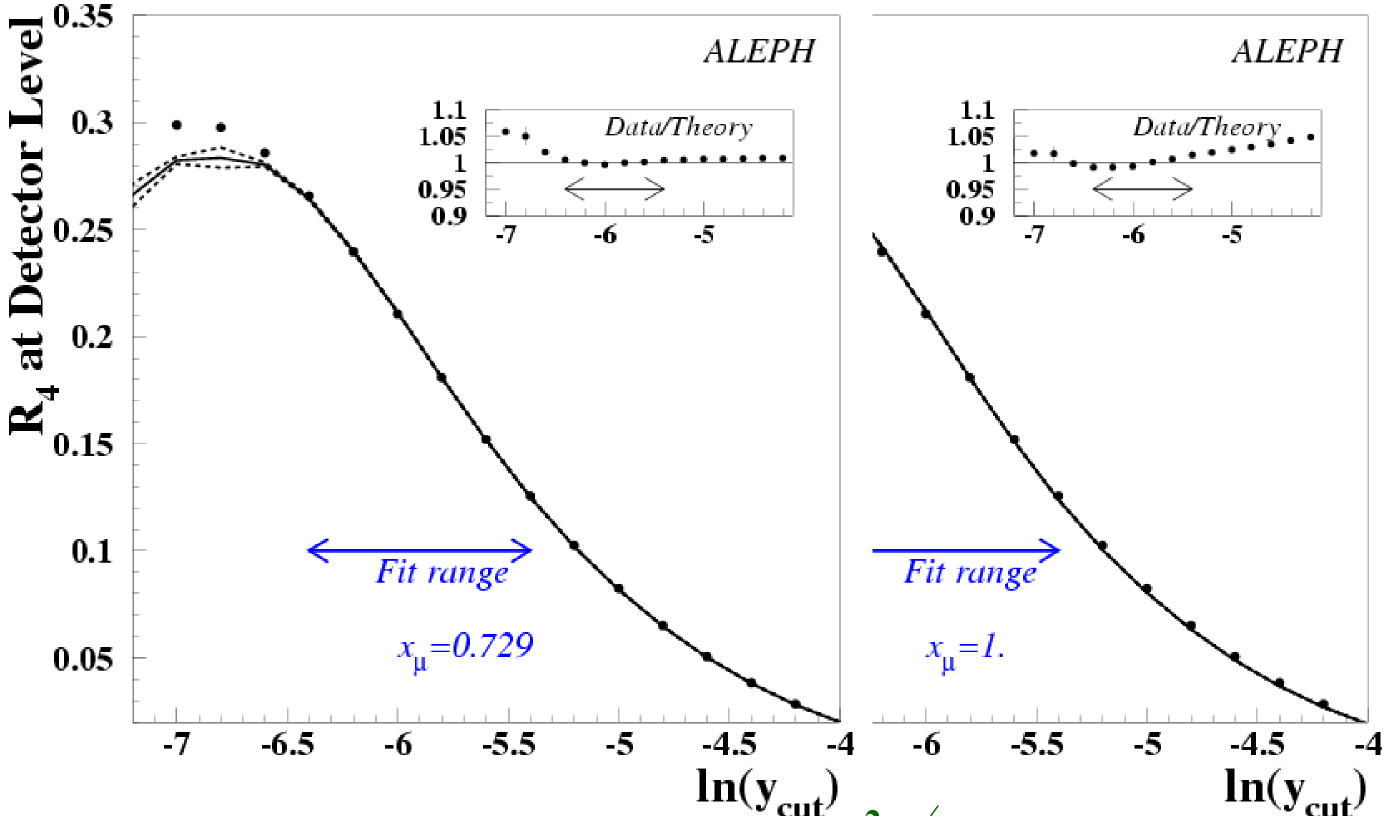
4-jet rate


ALEPH
χ^2/N_{dof}
η
x_μ


R_4
Fitted Resummed NLO pred., x_μ=0.73
ALEPH
-ln(y_{cut})


ALEPH
C^{tot}
ln(y_{cut})

4-jet rate



$$\chi^2 / N_{dof} = 27.6/5$$

$$\chi^2 / N_{dof} = 4.8/4$$

DELPHI NLO 4-jet rate, EOS Method

Durham: α_s **= 0.1178 ± 0.0012(exp) ± 0.0023 (hadr) ± 0.0014(scale)**

Cambridge: α_s **= 0.1175 ± 0.0010(exp) ± 0.0017 (hadr) ± 0.0007(scale)**