Measurements of the b-quark mass

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Introduction

- Why measure m_b?
  - One of the few parameters of the QCD Lagrangian
  - usually measured close to threshold ➡ independent measurement at much larger scale is interesting
  - basic input for test of m_b-m_τ unification (GUT)

- Basic problems:

  - quarks are not asymptotically free particles
  - masses are effective parameters
  - different definitions possible

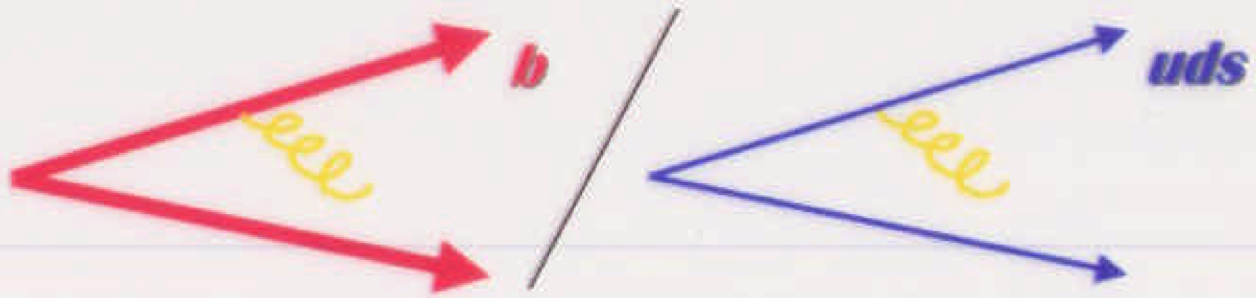
$\overline{MS}$ running mass $m_b(\mu)$

Pole mass M_b

Theory

Dynamical as well as phase space effects reduce radiation in b-quark events

$R_{b/l} =$



Calculations by
Rodrigo et al.,
Bernreuther et al.,
Nason et al.

$$R_{b/l}(X) = 1 + \frac{m_b^2}{m_Z^2}\left(b_0(m_b, X) + \frac{\alpha_s}{2\pi} b_1(m_b, X) \right)$$

Inclusive quantities (eg. σ_{tot})

$b_0 \approx 1$ $R_{b/l} = 1 +$ **few ‰**

Semi-Inclusive quantities (eg. R_3)

$b_0 >> 1$ $R_{b/l} = 1 +$ **few %**

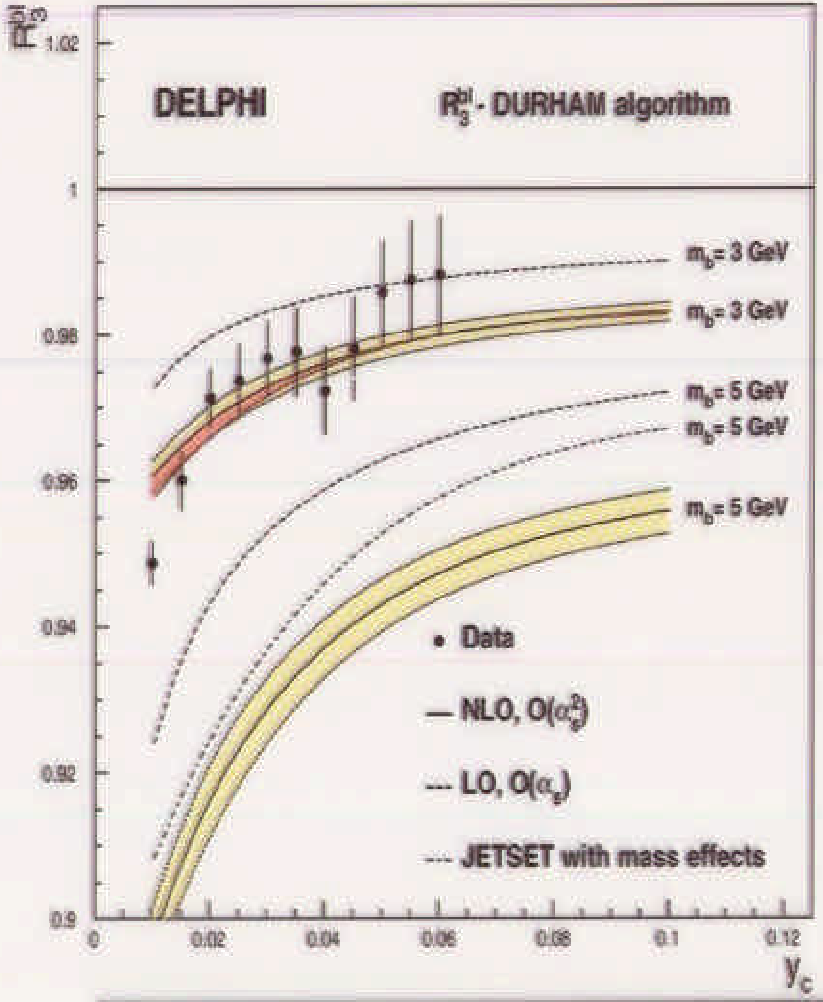
Experimental Method

- Select $e^+e^- \to q\bar{q}$ events
- Tag events of different flavours
- Measure $R_{b/l}$ (X)
- Correct for hadronization, detector, flavour and tag bias
- Extract m_b from

$$R_{b/l}(X) = 1 + \frac{m_b^2}{M_Z^2}\left[b_0(X,m_b) + \frac{\alpha_s(\mu)}{2\pi} b_1(X,m_b)\right]$$

Experiment

Theory

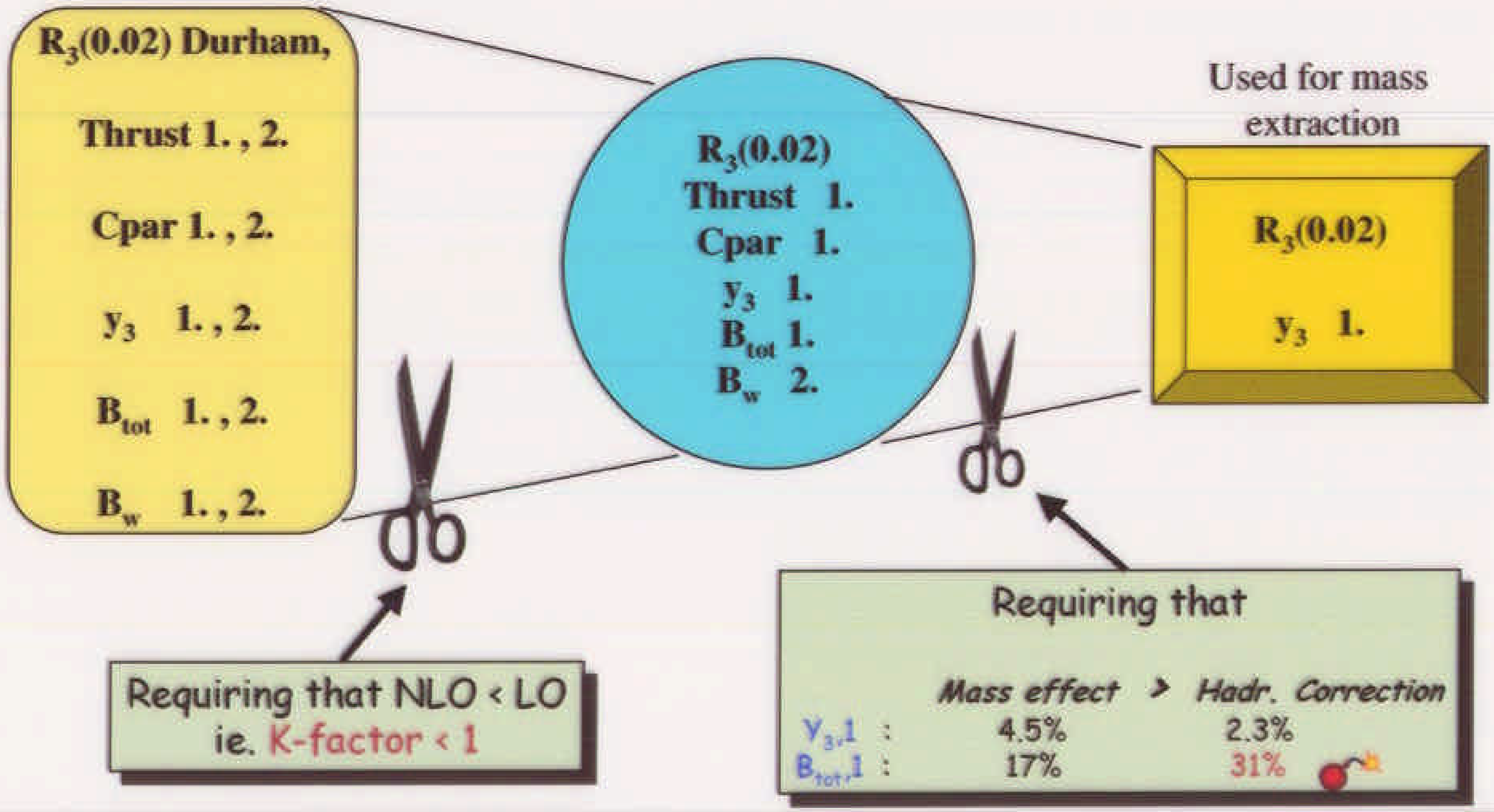


First measurement by DELPHI in 97/98

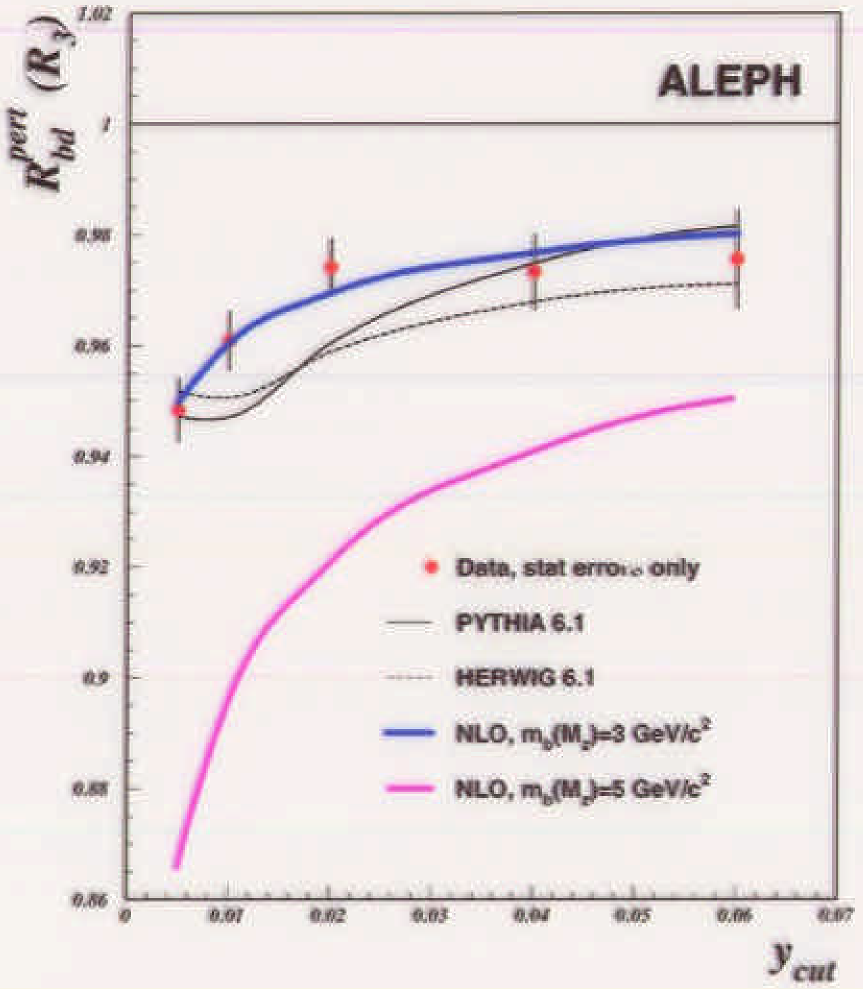
ALEPH Analysis

(CERN-EP/2000-093, subm. to Eur.Phys. J. C)

In addition to $R_3(y_{cut})$, studied first (1.) and second (2.) moments of event shape variables



ALEPH Results



Running b quark mass (in GeV/c²)

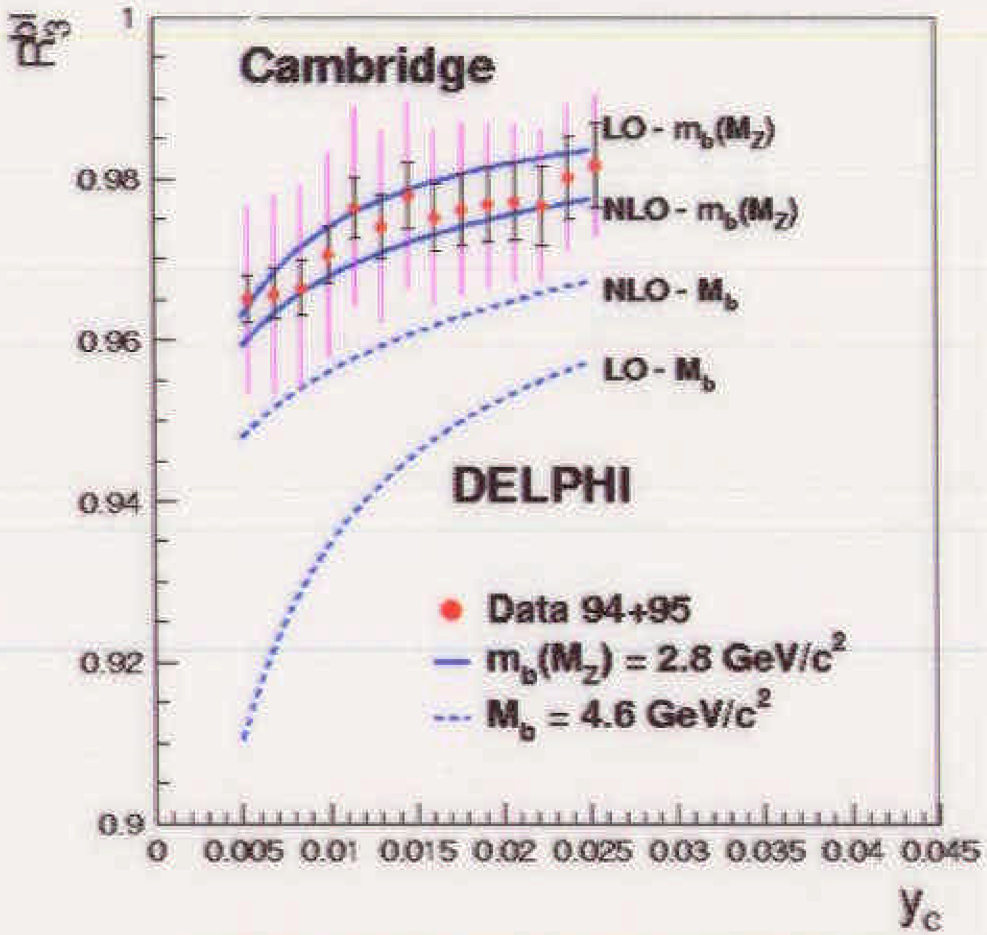
Variable	$m_b(M_Z)$	±(stat)	±(exp)	±(had)	M_b
$Y_{3\iota}$	3.34	0.22	0.22	0.38	4.73
$R_{3jet}(0.02)$	2.76	0.28	0.28	0.62	3.65

Taking the one with the smallest error, applying a scheme correction and adding theoretical uncertainty

$$m_b(M_Z) = (3.27 \pm 0.22_{(stat)} \pm 0.22_{(syst)} \pm 0.38_{(had)} \pm 0.16_{(theo)}) \text{ GeV}/c^2$$

DELPHI analysis

- First analysis on 92+93+94 data
- Two new analyses on 3 jet rate on 94+95 data
  - Durham and Cambridge (smaller NLO corrections)
  - Use improved tag (vertex + shape) and compare with old to establish tag systematic
- Consistent results found
- Cambridge shows better convergence for running mass than for pole mass



$$m_b(M_Z) = 2.61 \pm 0.18\ (stat)\ {}^{+0.45}_{-0.49}\ (had)$$
$$\pm 0.18\ (tag) \pm 0.07\ (theo)$$
$$= 2.61 \pm 0.54\ \text{GeV}$$

Comparison

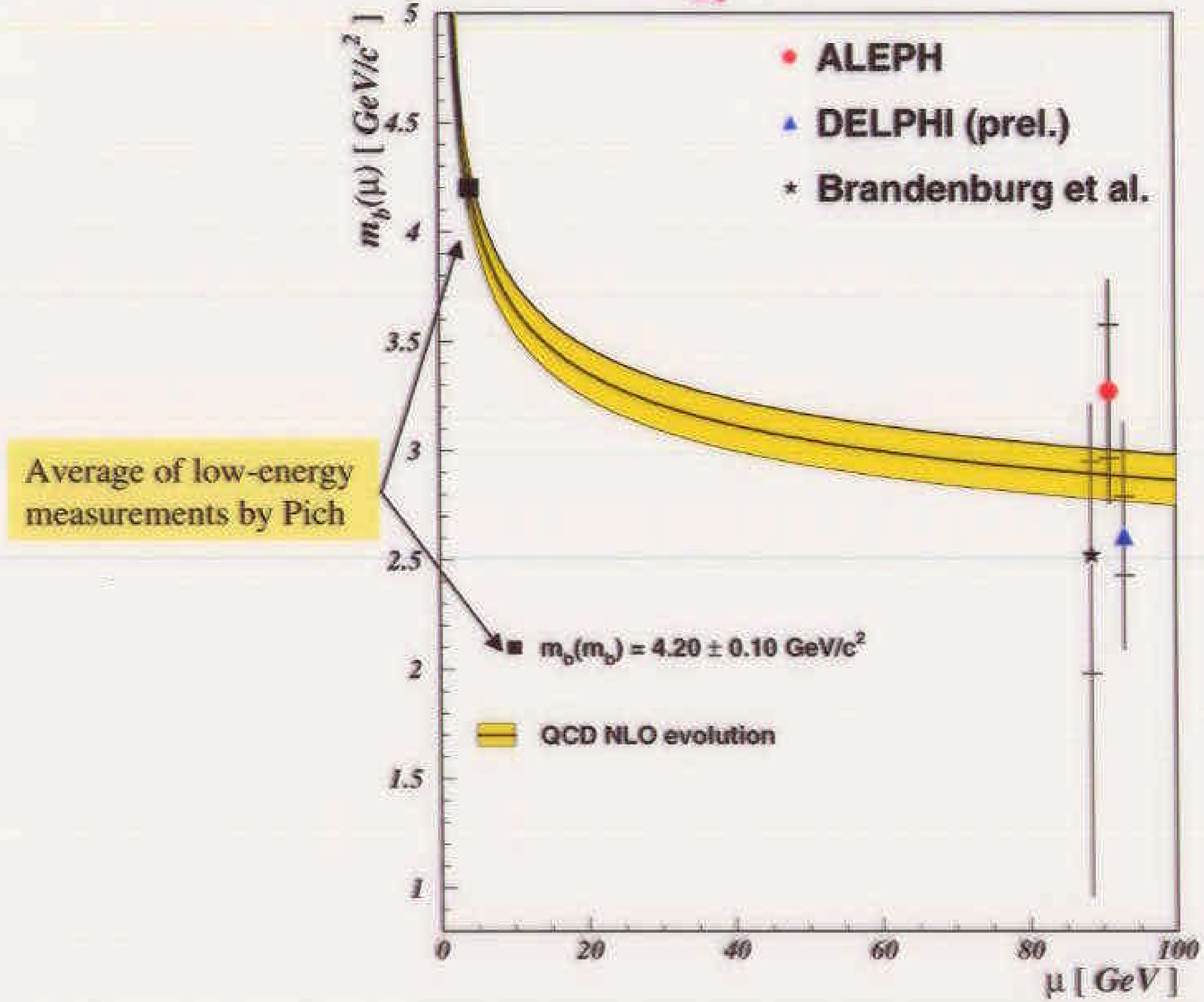
	$m_b(m_Z)$	Stat	Syst	Had	Scale	Scheme	Total
Aleph $y3_1$ Durham	3.27	0.22	0.22	0.38	0.15	0.07	0.52
Aleph 3jet Durham (0.02)	2.56	0.28	0.28	0.62	0.06	0.20	0.76
Delphi 3jet Durham (0.02)	2.81	0.25	0.20	0.34	0.10	0.25	0.54
Delphi 3jet Cambridge (0.005)	2.61	0.18	0.18	+0.45 -0.49	0.03	0.07	0.54

3 Jet rate ⇒ big hadronization errors

(even depending on jet algorithms)

Barely compatible with $y_{3,1}$

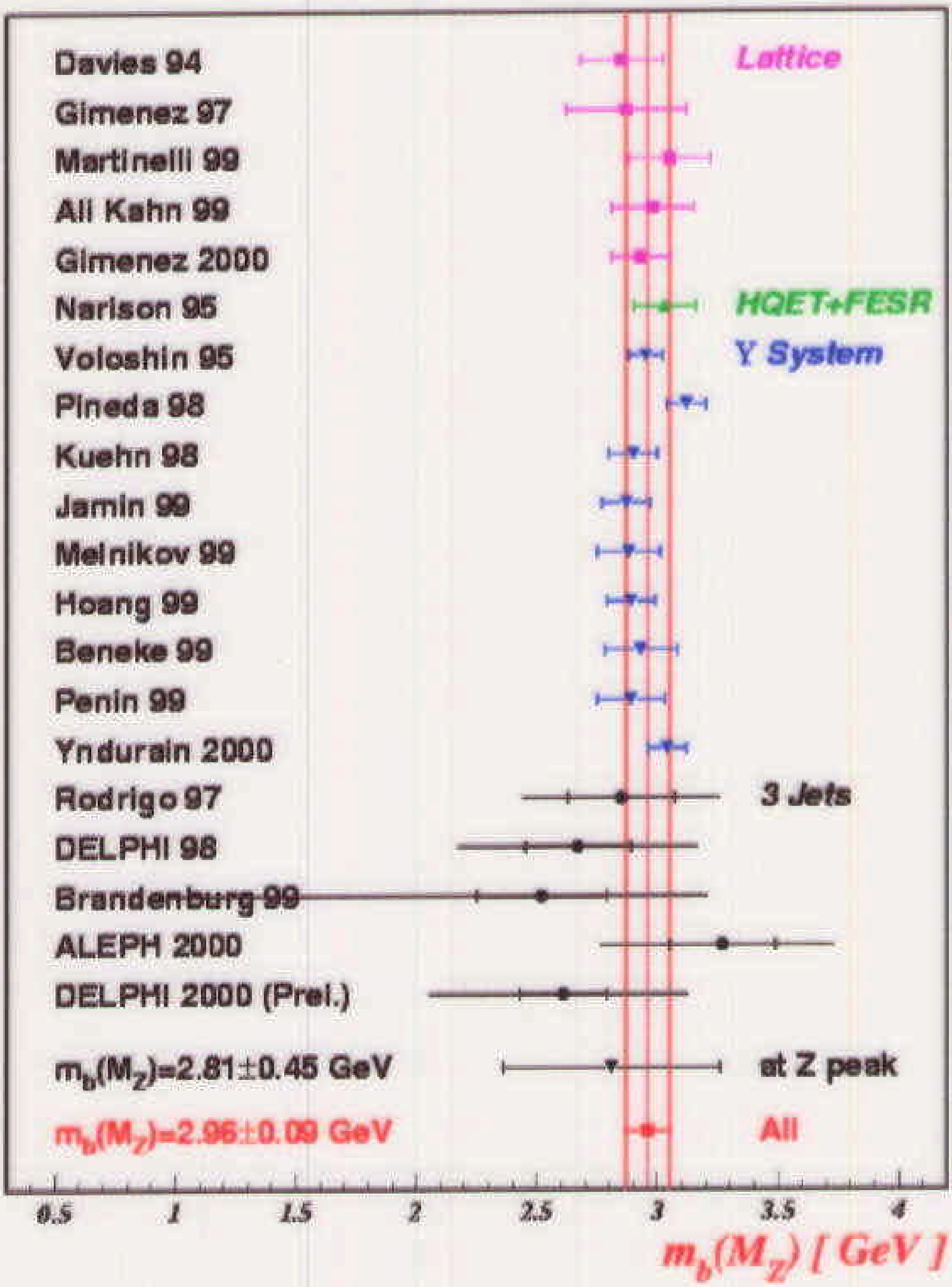
The  of $m_b(\mu)$


ALEPH
DELPHI (prel.)
Brandenburg et al.
Average of low-energy measurements by Pich
$m_b(m_b) = 4.20 \pm 0.10$ GeV/c^2
QCD NLO evolution
$m_b(\mu)$ [GeV/c^2]
5
4.5
4
3.5
3
2.5
2
1.5
1
0
20
40
60
80
100
μ [GeV]

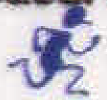
Summary of m_b measurements

Compilation by Gimenez et al. and J. Fuster

Averaging method by M.Schmelling



Conclusions

- The b-quark mass has been measured at the Z peak and consistency with the predicted  is found
- ALEPH: a large set of observables used to study the running b-quark mass

  $y3_1$ gives the smallest systematic error
- DELPHI: the Cambridge jet algorithm shows
  - Very nice theoretical errors but still suffers from hadronization systematics
  - Very good agreement with NLO calc. based on the running b-quark mass
- *Good agreement between ALEPH and DELPHI using the 3-Jet rate*
- *Marginal agreement with first moment of y3*
- *some further understanding of hadronization corrections needed?*