Improved measurements of the b quark mass at LEP

- Motivations to measure m_b at M_Z.
- Observables sensitive to m_b at M_Z.
- Experimental strategy.
- Systematic uncertainties.
- Results (DELPHI and OPAL).
- Conclusions.

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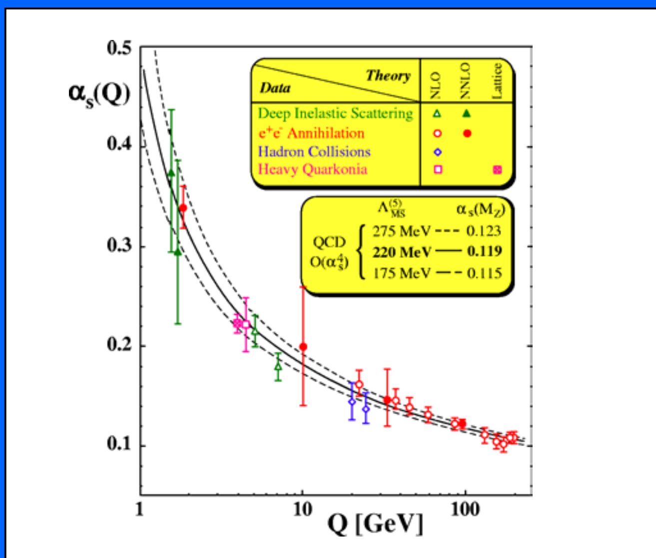
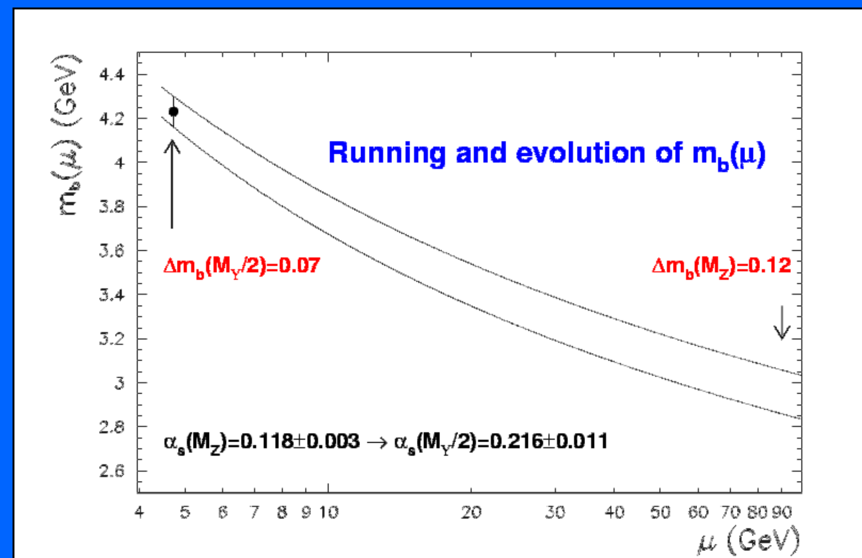
Motivations to measure m_b at M_Z

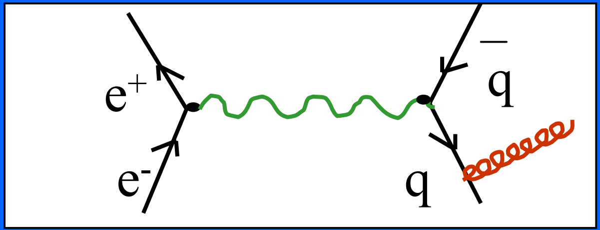
- Direct and independent measurement of the b mass at high energy.
- In the case of $m_b(\mu)$, test of the evolution with the scale.





- $m_b(M_Z)$ is a basic input parameter to test m_b-m_τ unification predicted by GUT models at $M_{GUT} \sim 10^{16}$ GeV.

Observables sensitive to m_b at M_Z



- Due to the mass effect, massive quarks radiate less gluons than light quarks.
- For inclusive observables, b mass effects are negligible at LEP ($m_b^2/m_Z^2 \leq 0.3\%$).
- For jet rates: $\exists\ y_c \rightarrow (m_b^2/m_Z^2)/y_c$ sizeable effects.
- The observable used:

$$R_n^{bl}(y_c) = \frac{\Gamma_{nj}^{Z^0 \to b\bar{b}(n-2)g}(y_c) / \Gamma_{tot}^{Z^0 \to b\bar{b}}}{\Gamma_{nj}^{Z^0 \to l\bar{l}(n-2)g}(y_c) / \Gamma_{tot}^{Z^0 \to l\bar{l}}}$$

NLO for n = 3 jets
LO for n = 4 jets

DELPHI: n = 3, 4 jets
Durham, Cambridge.

OPAL: n = 3 jets
Jade, E0,P, P0, E,Geneva,Durham.

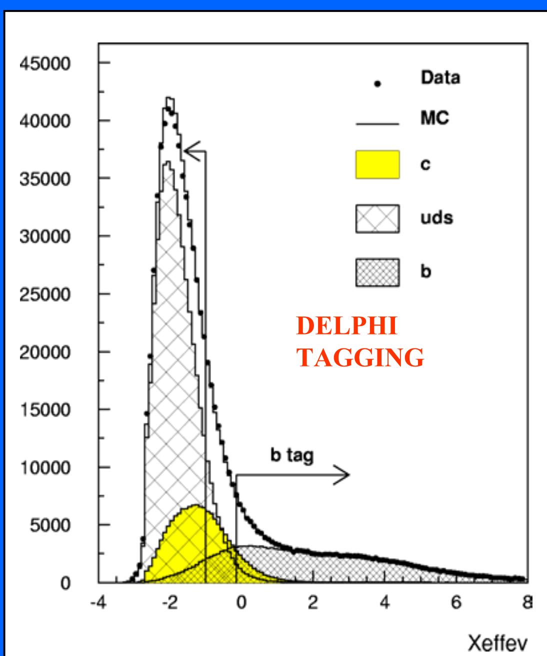
$m_b(M_Z) \Leftrightarrow \alpha_s$ universality

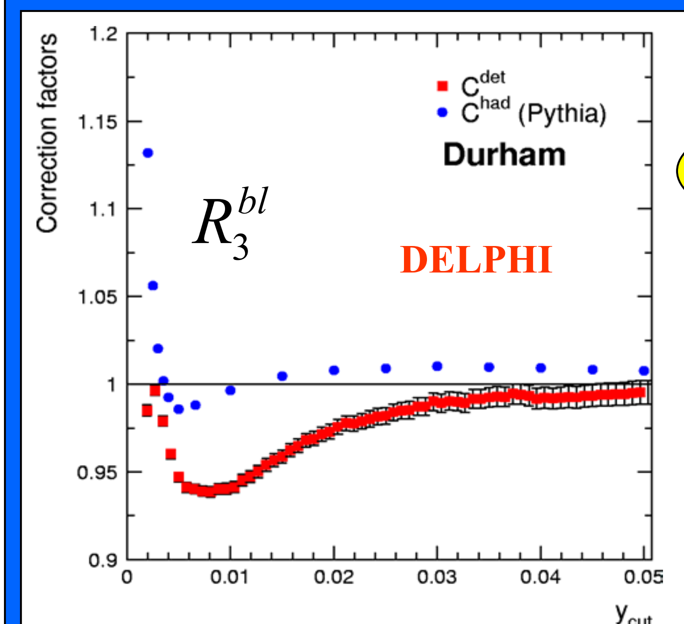
Experimental Strategy

Data ⟹ **Hadronic selection** ⟹ $Z^0 \to q\bar{q}$ ⟹ **Tagging** ⟹ $\begin{cases} Z^0 \to b\bar{b} \\ Z^0 \to l\bar{l} \end{cases}$ ⟹ **Jet reconstuction** ⟹ $R_n^{bl-\mathrm{det}}$

⇓ **Detector simulation**

R_n^{bl-had} ⟹ **Hadronization** (**Pythia Herwig**) ⟹ $R_n^{bl-part}$





Systematic uncertainties

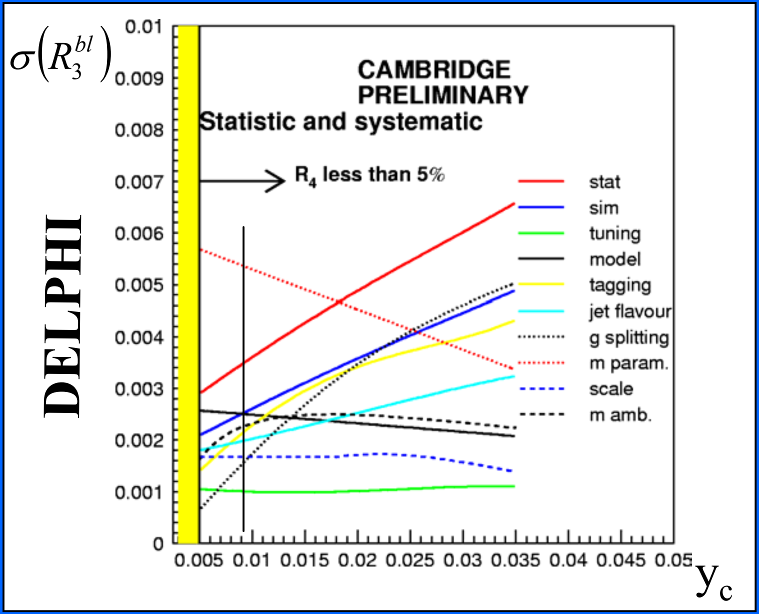
Detector and physics modelling:

- Detector resolution.
- Tagging (τ_b, R_b, $n_{ch}^{B\text{-decays}}$, ε_b, ε_c).
- gluon splitting rates.

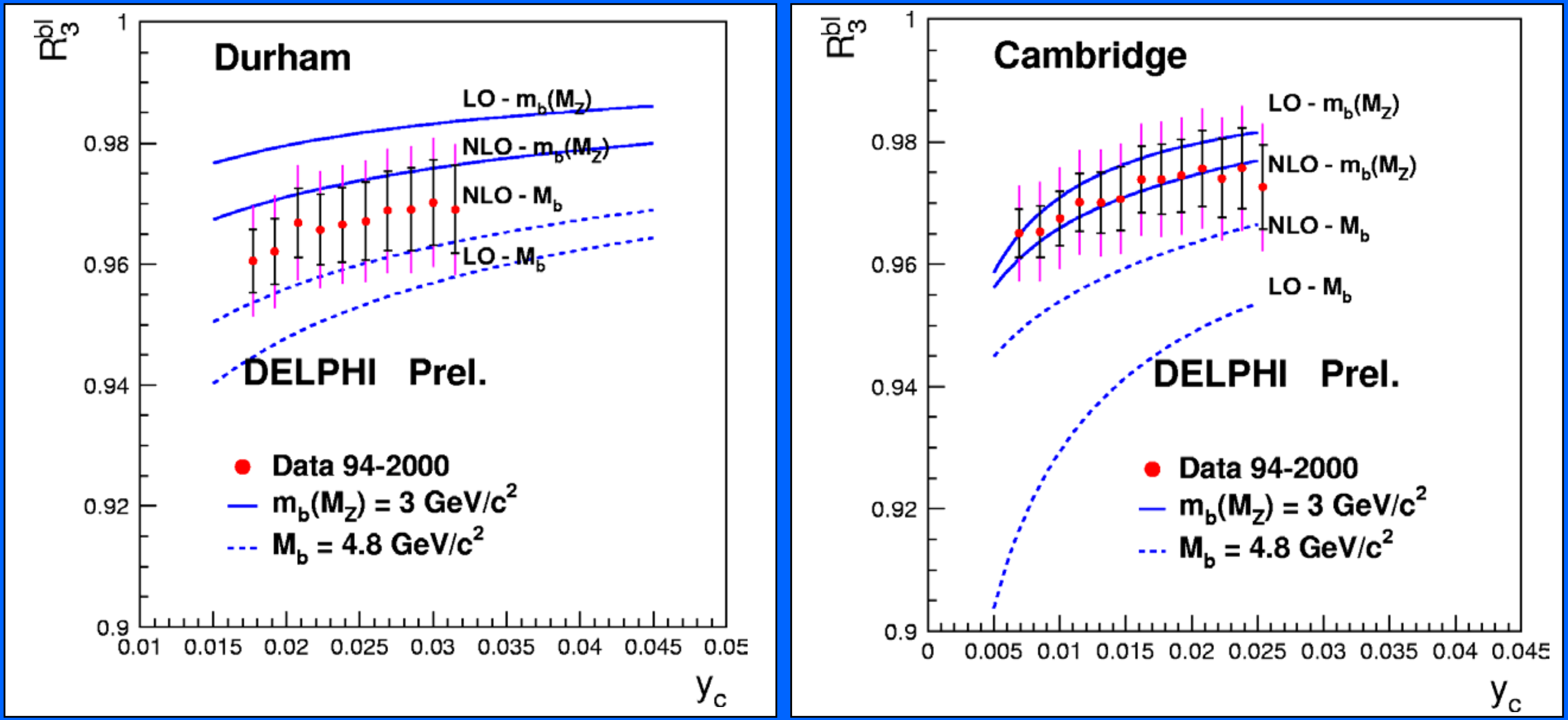
Hadronization:

- Tuning of the fragmentation parameters.
- Model (string or cluster).
- b fragmentation function.
- b mass parameter in the generator.

OPAL DURHAM	$R_3^{bl}(y_c=0.01)$
Result	0.9532
Statistics	±0.0056
Detector simulation	±0.0143
$\lvert\cos(\theta_{thrust})\rvert \leq 0.75 \pm 0.05$	±0.0011
$L/\sigma_L \geq 8$	±0.0041
$N_{charged}$ (decay) = 4.955±0.062	±0.0010
τ_b = (1.564±0.014) ps	±0.0005
R_b = 0.2175±0.013	±0.0007
b quark fragmentation	±0.0059
c quark fragmentation	±0.0001
b = (0.52 ± 0.05) GeV^2	±0.0013
σ_q = (0.40 ± 0.05) GeV	±0.0012
Q_0 = (1.90 ± 0.05) GeV	±0.0036
M_b^{JETSET} = (5.0 ± 0.05) GeV	±0.0000



DELPHI results

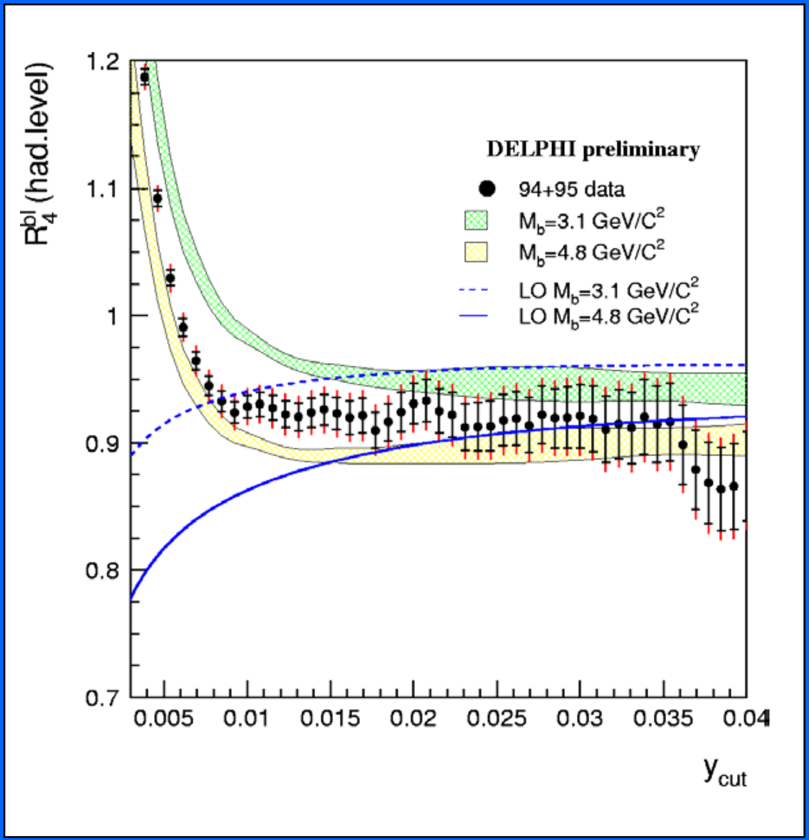


Durham: $m_b(M_Z) = 2.99^{+0.25}_{-0.27}\,(\text{stat})^{+0.34}_{-0.37}\,(\text{syst}) \pm 0.28\,(\text{theo})$

Cambridge: $m_b(M_Z) = 2.82 \pm 0.19\,(\text{stat})^{+0.31}_{-0.33}\,(\text{syst}) \pm 0.06\,(\text{theo})$

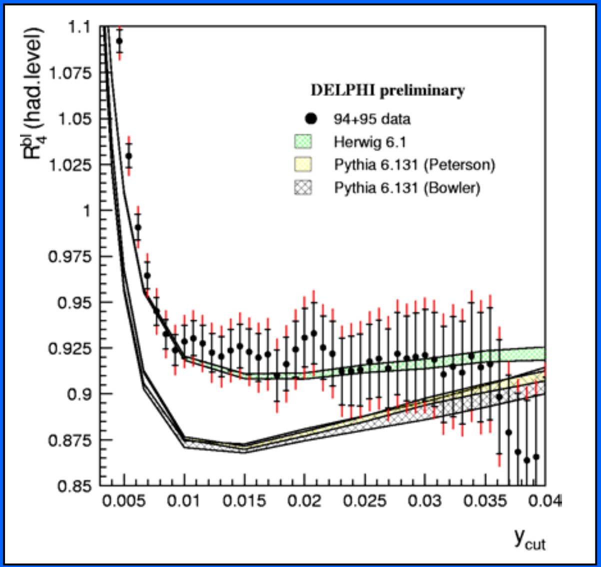
$\alpha_s^b / \alpha_s^l = 1.001 \pm 0.004\,(\text{stat}) \pm 0.007\,(\text{syst}) \pm 0.002\,(\text{theo})$

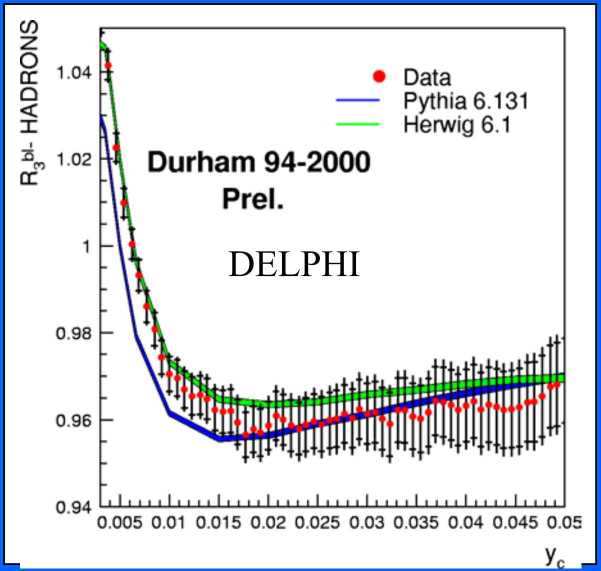
First look into 4 jets



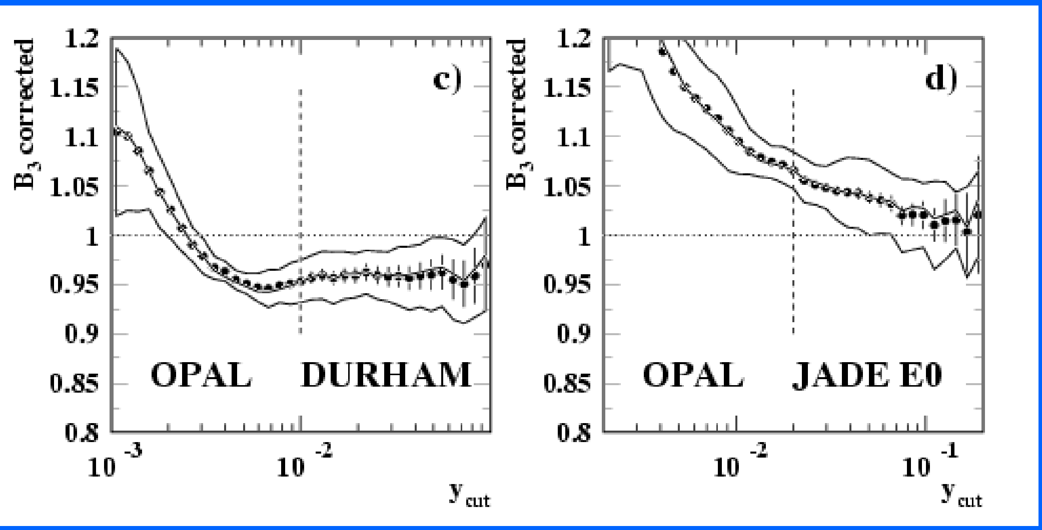
Data lies between the LO predictions for M_b = 3 - 4.8 GeV.

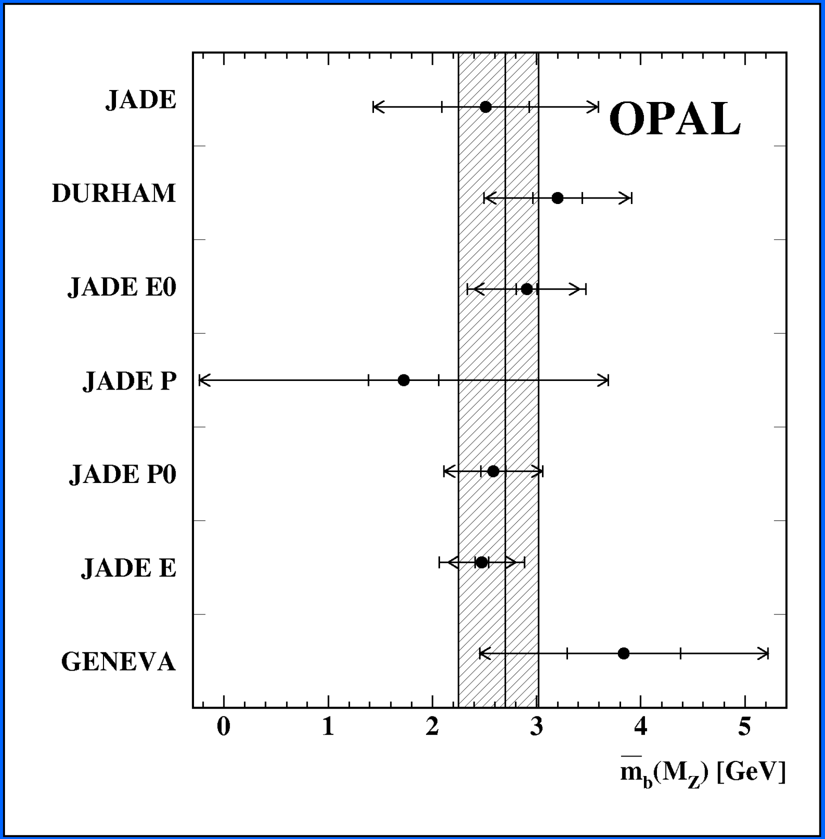
Modelling of the generators





OPAL results

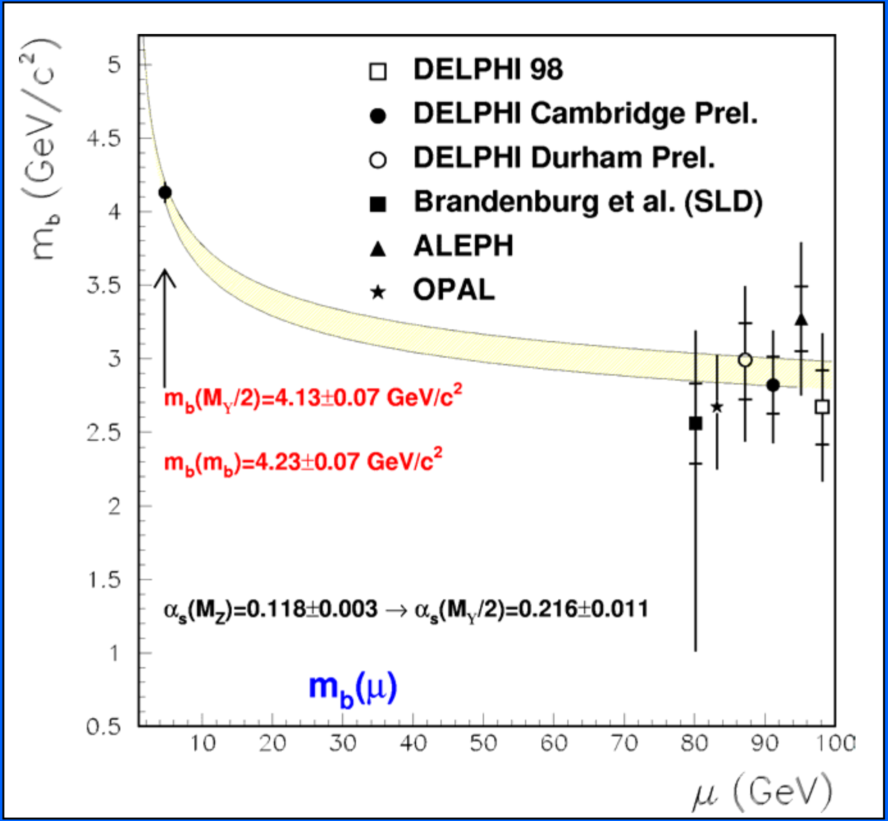




The 7 results of $m_b(M_Z)$ were combined:

$$m_b(M_Z) = 2.67 \pm 0.03\,(\text{stat})^{+0.29}_{-0.37}(\text{syst}) \pm 0.19\,(\text{theo})$$

Conclusions



- b mass effects have been measured with 4 jet events!

NLO calculations are welcome!

- All measurements of $m_b(M_Z)$ are compatible.
- The shift $m_b(M_\Upsilon/2)$ -$m_b(M_Z)$ has been observed with almost 4σ in agreement with the QCD prediction.
- The values obtained for M_b (~4.2 GeV) are lower than the ones obtained at low energy.
- A better understanding of the mass entering in the MC could lead to a precision on $m_b(M_Z)$ of about 250-300 MeV.