http://home.cern.ch/ pubxx/tasks/wphysics/4f/www/Discussion/bbg.html

Towards estimating the uncertainty in the modeling of the 4-jet event rate with b-quarks arising from QCD processes at LEP-200

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DELPHI Collaboration

Outlook

- Introduction
- Procedure
- NLO vs LO in three-jet production
- Results at $\sqrt{S} = m_Z$
- Results at $\sqrt{S} = 189$GeV
- Conclusion

Introduction

DELPHI observes global excesses of b-tagged four-jet events at 189 GeV with respect to the MC

Relevant for Higgs and ZZ searches

The goal: to study the theoretical precision in the modeling of the four-jet rate at LEP-1 and LEP-2 involving b-quarks

- We study the theoretical uncertainty due to the unknown of higher orders in perturbation theory in Matrix Element (ME) calculations including quark masses
- And compare the ME calculations to the predictions of the parton shower (PS) algorithms implemented in JETSET

Quark mass corrections

Because of its mass, gluon radiation from b-quarks is suppressed as

$$\frac{1}{y_c}\left(\frac{m_b^2}{s}\right)$$

- at higher energies weaker effect
- but jets are defined with small y_c to maximize signal efficiencies $\rightarrow$ effect still important

State of multi-jet ME calculations with massive quarks in e^+e^- annihilation

- three- and four-jet rates at leading order (LO) for massive quarks (Ballestrero, Maina, Moretti)
- three-jet rate at next-to-leading order (NLO) for massive quarks (Santamaria, Bilenky, G.R.) (Bernreuther, Brandenburg, Uwer) (Nason, Oleari)
- four-jet rate at NLO for massless quarks (Dixon, Signer) (Trocsanyi, Nagy)

$\rightarrow$ four-jet rate at NLO for massive quarks $\boxed{\text{long term project}}$

- fully numerical approach (Soper) ?

Until four-jet rate at NLO for massive quarks completed

- What to do ?
- How to estimate higher order corrections ?

Procedure

Only LO massive ME calculations of four-jet rates available

- we estimate the theoretical uncertainty associated to our ignorance of the higher order terms in perturbation theory as the band defined by the LO predictions for
  - a $M_b \simeq 5$ GeV$/c^2$ b-quark pole mass
  - a $m_b(s) \simeq 3$ GeV$/c^2$ b-quark running mass

Quark are not free particles $\rightarrow$ one can use different quark mass definition in ME calculations

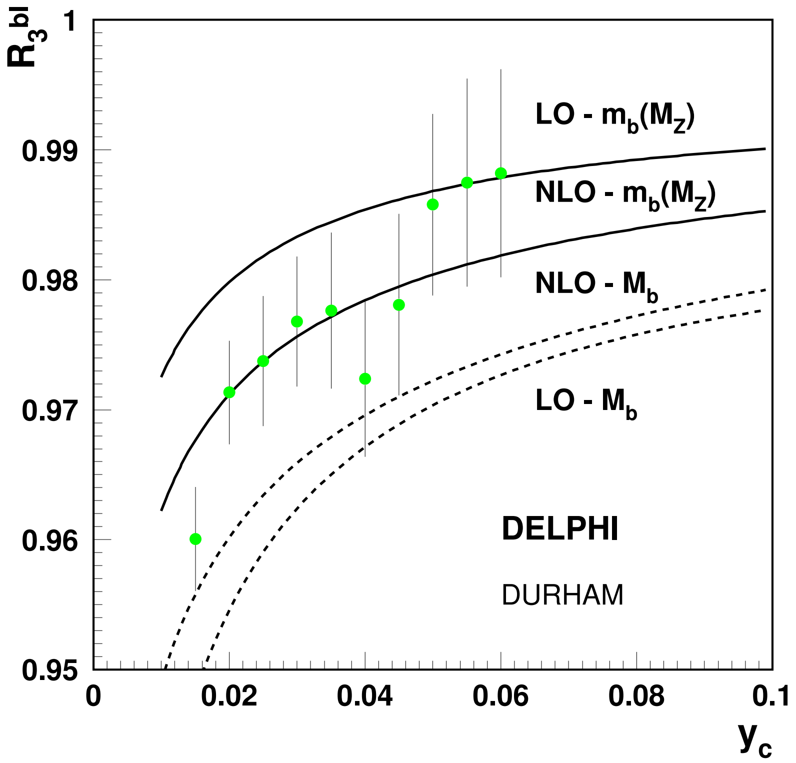
$$M_b = M_b(m_b(\mu), \alpha_s(\mu), \mu)$$

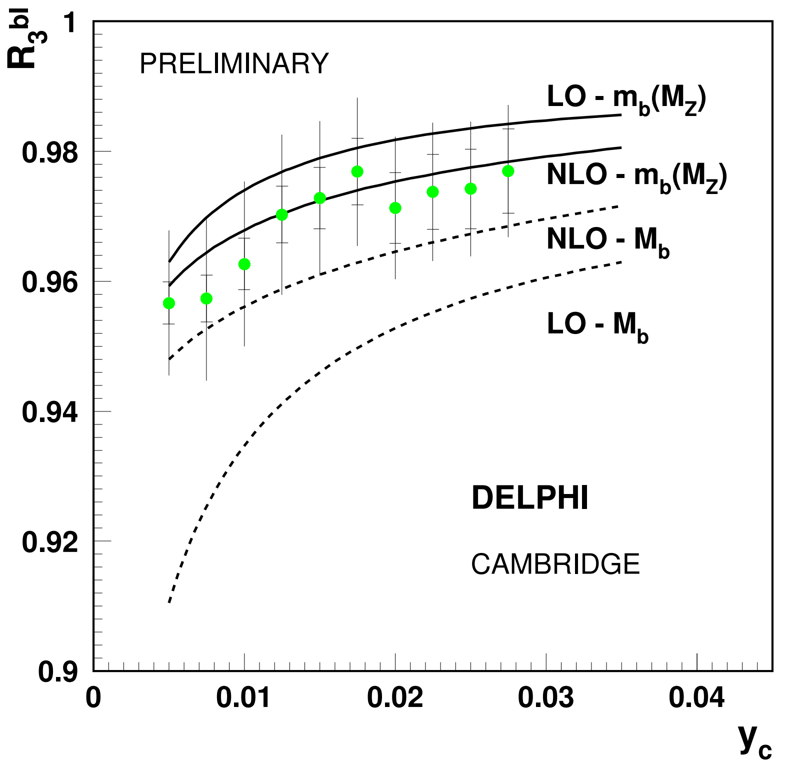
Formally we can change the value of μ, α_s and $m_b(\mu)$, keeping the physics unchanged

- But at a fixed order strong dependence on which mass definition is used (as well as residual dependence on μ)
- The more higher orders are included the smaller residual dependence on the mass definition and μ remains

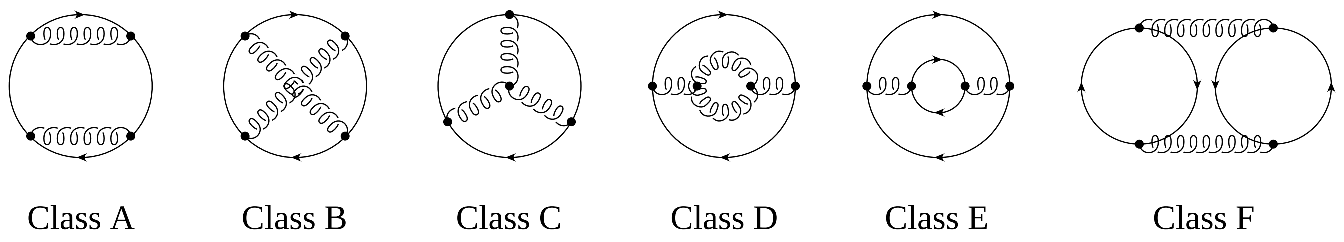
NLO vs LO in three-jet production

$$R_3^{b\ell} = \frac{[\Gamma_{3j}(y_c)/\Gamma_{tot}]^{Z\to b\bar{b}}}{[\Gamma_{3j}(y_c)/\Gamma_{tot}]^{Z\to \ell\ell}} \,, \qquad \ell = u, d, s$$





ME calculation of four-jet rates



all the cuts given a four parton final state integrated in the four-jet region of phase-space defined by several jet-clustering algorithms: Durham, Jade

- Free of IR divergences
- gluon splitting: Class E with b-quarks in the internal loop and light-quarks in the external loop considered as light events
- Interferences (Class F) neglected

Ratio of four-jet rates

$$\boxed{R_4^{b\ell} = \frac{\left[\sigma_{4j}(y_c)/\sigma_{tot}\right]^{e^+e^-\to b\bar{b}}}{\left[\sigma_{4j}(y_c)/\sigma_{tot}\right]^{e^+e^-\to \ell\bar{\ell}}}\ , \qquad \ell = u, d, s}$$

Interpret $R_4^{b\ell}$ as the suppression of gluon radiation from primary b-quarks

- Heavy quarks radiate less gluons than massless quarks: $R_4^{b\ell} < 1$
- Massless limit: $R_4^{b\ell} = 1$ for $m_b = 0$

Parameterization

$$R_4^{b\ell} = 1 + \frac{m_b^2}{s}\left[\sigma(s) H\left(\frac{m_b^2}{s}, y_c\right)\right]$$

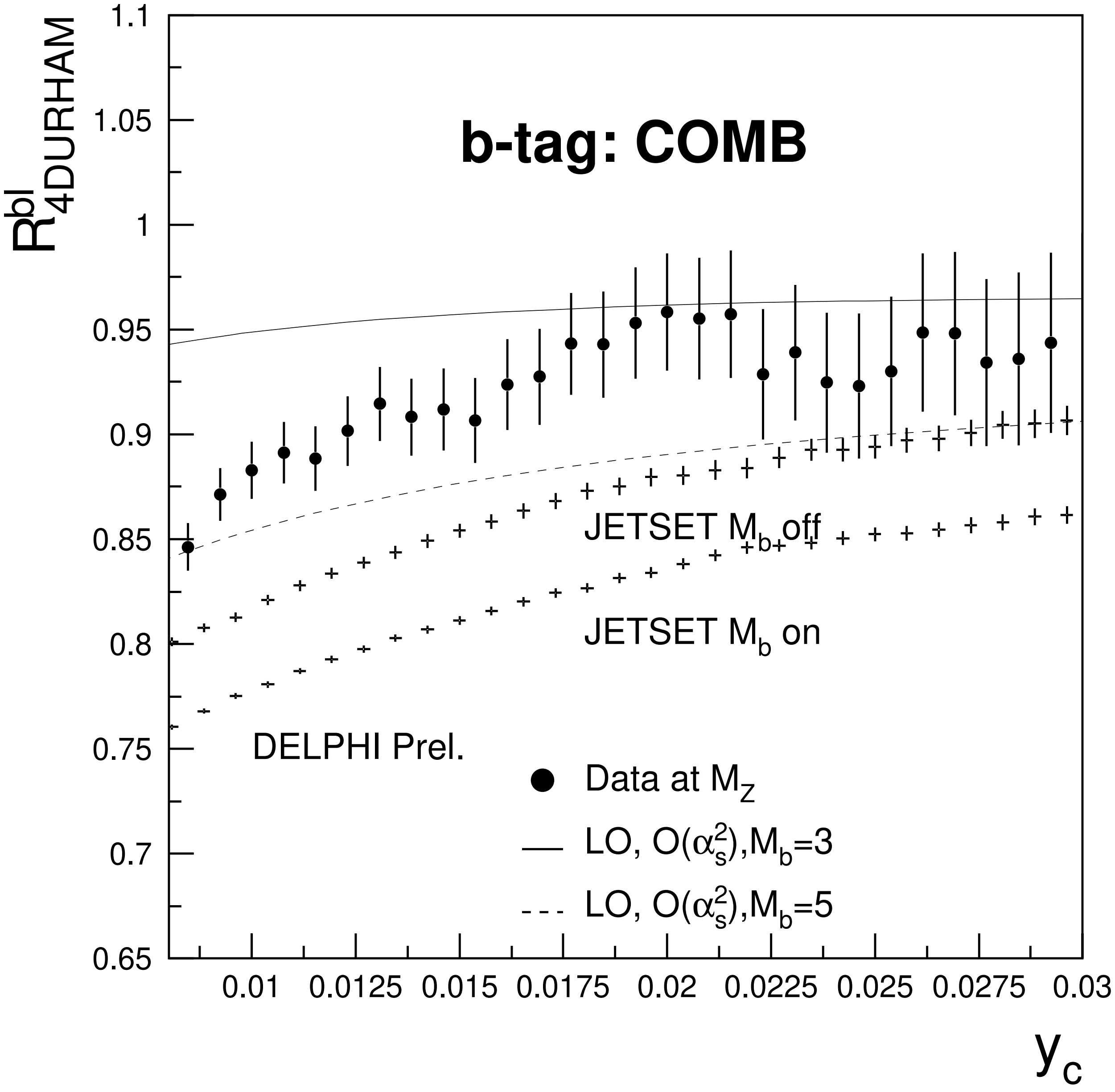
- $\sigma(s)$: vector and axial couplings of b-quarks to the Z-boson $+$ photon exchange
- the function $H(m_b^2/s, y_c)$ fitted to

  $$H\left(\frac{m_b^2}{s}, y_c\right) = f_1(y_c) + f_2(y_c)\log\left(\frac{m_b^2}{s}\right) + f_3(y_c)\frac{m_b^2}{s}$$

  with

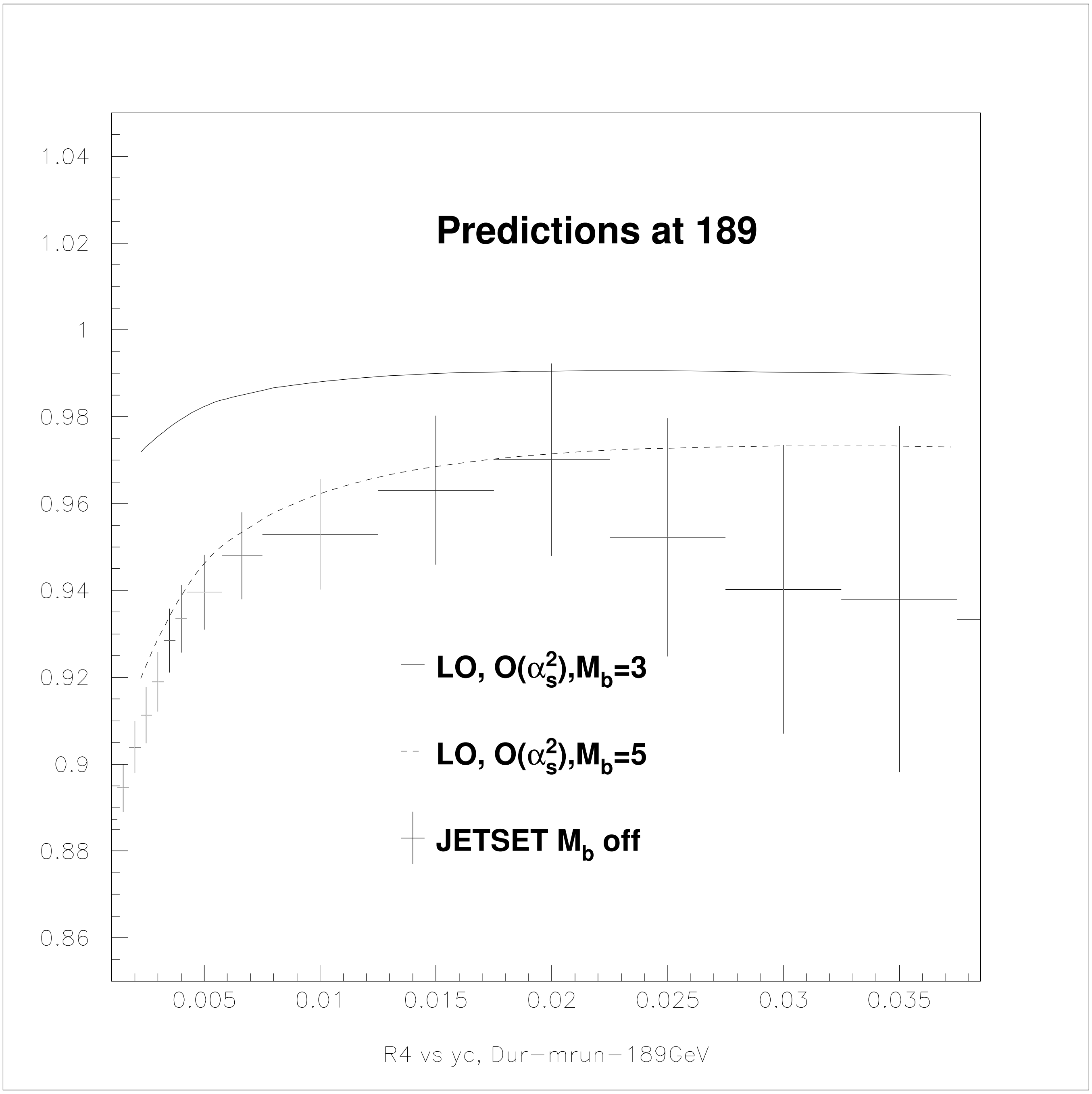
  $$f_i(y_c) = \sum k_n^{(i)} \log^n(y_c)$$

Results at $\sqrt{S} = m_Z$



- LO($m_b = 3$ GeV)-LO($m_b = 5$ GeV) $\sim$ 10%

Results at $\sqrt{S} = 189$GeV



- LO($m_b = 3$ GeV)-LO($m_b = 5$ GeV) $\sim$ 2% but $\sim$ 5% at small-y_c

Conclusion

- LO ME calculations including mass effects result to be more in line with the experimental data within a $\pm 5\%$ at LEP-1

- NLO corrections would be desirable, but will not be available soon