

Enhancement of hadronic b-quark decays

Joint DPF/JPS Pacific Region Meeting

Waikiki, November 2006

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Outline

Introduction: semileptonic and hadronic decay modes of the b quark;

Theoretical prediction of the SL branching fraction and its conflict with experiment;

New perturbative corrections

Outlook: need to account for the charm mass

50th anniversary of radiative corrections (for charged particle decays)

1956: Behrends, Finkelstein, Sirlin,
'Radiative corrections to decay processes'

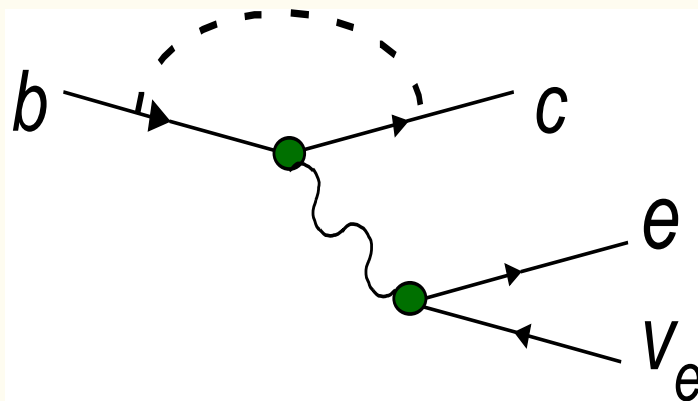
Muon decay: electron spectrum, total rate

1996: first result at two loops (zero recoil)

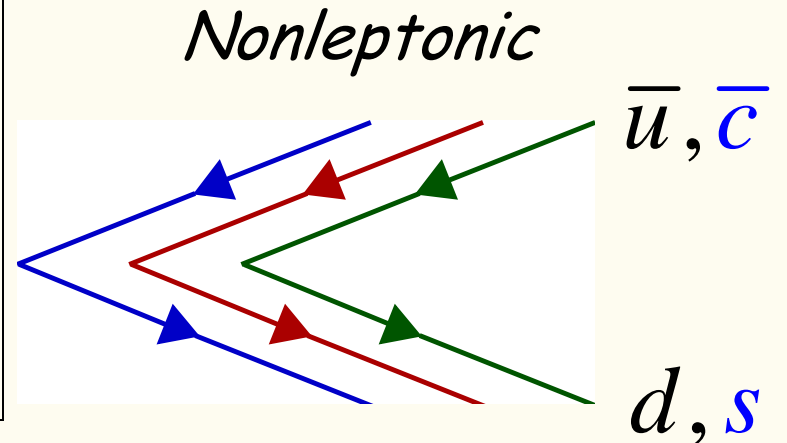
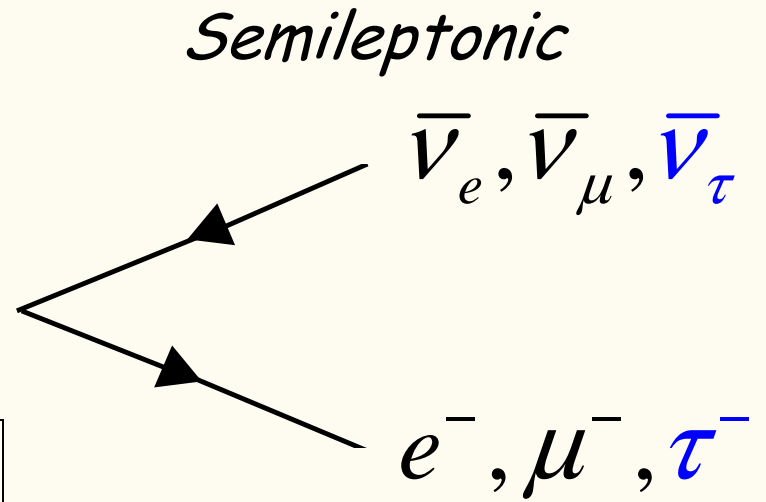
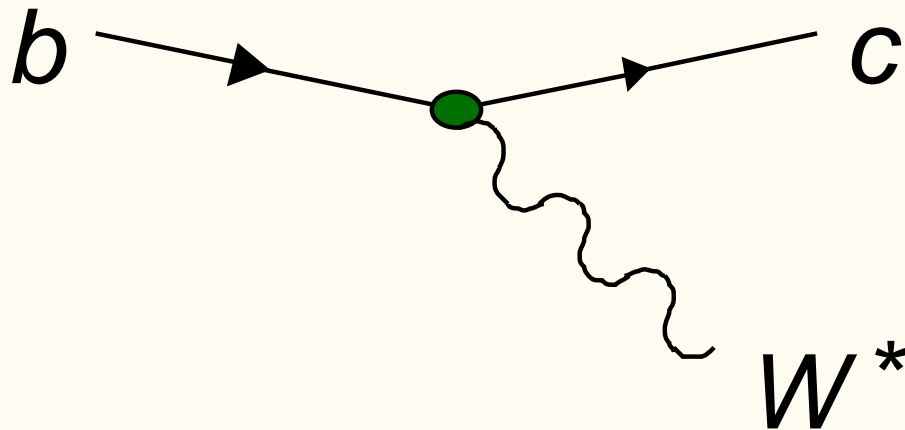
1999: complete muon lifetime (van Ritbergen, Stuart); $b \rightarrow u$ (ν_R)

2005: complete muon spectrum (Anastasiou, Melnikov, Petriello)

So far always
only two charged
particles:



How does b quark decay?



Semileptonic branching ratio
(parton model without QCD)

$$B_{SL} \approx \frac{1}{3+6} \approx 11\%$$

$$\Delta B_{SL} = \frac{1}{3+6} - \frac{1}{3+6(1+\delta)} \approx \frac{6\delta}{81} = \frac{\delta}{13.5}$$

8% shift of the NL width shifts B_{SL} by 0.6 percentage points

What do experiments get for B_{SL} ?

World average: $(10.76 \pm 0.23)\%$

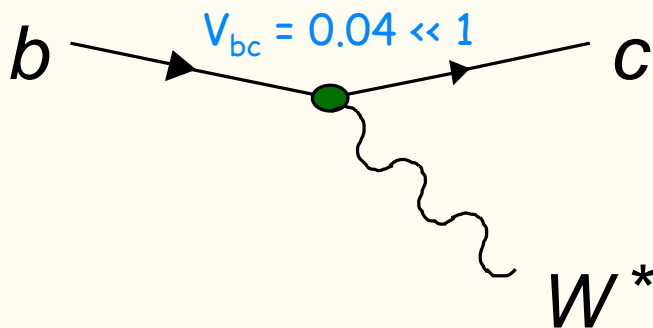
hep-ex/0505100
(without $b \rightarrow u$)

Theoretical lower limit:

$$B_{SL}(b \rightarrow ce\bar{\nu}_e) > 11.5\%$$

Bigi et al, 1994
Voloshin, 2000

3.2σ difference



Standard Model suppressed:
good place to look for New Physics

The puzzle of the low semileptonic branching

Physics Letters B 323 (1994) 408–416
North-Holland

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1 FEBR

Inconclusive inclusive nonleptonic B decays

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branching ratio of
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The baffling semileptonic branching ratio of B mesons

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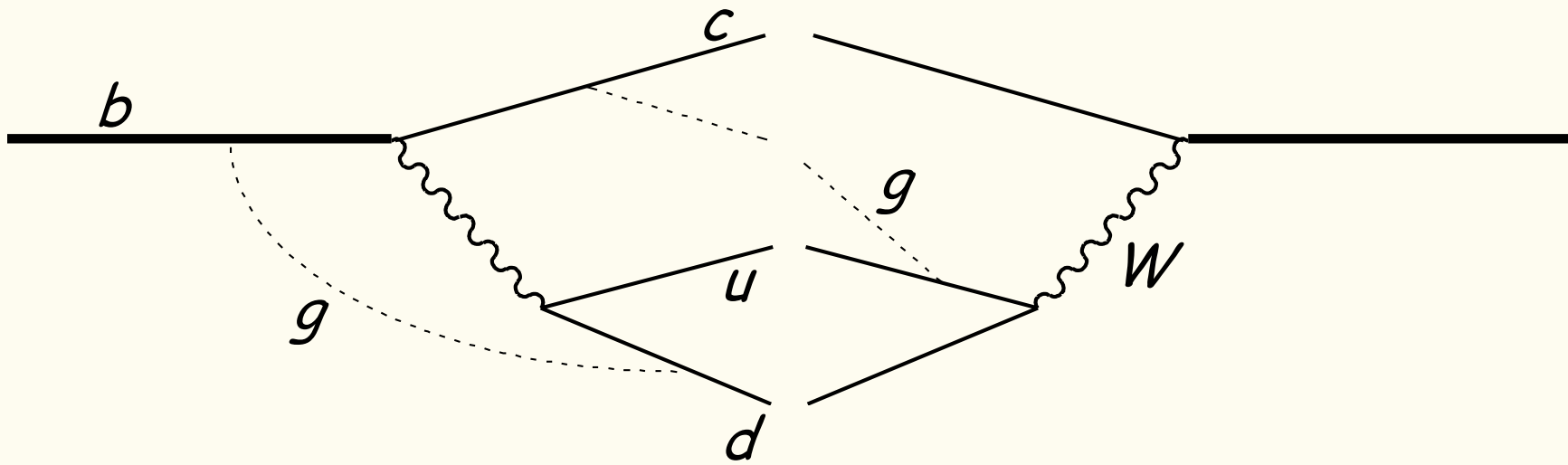
Received 10 December 1993

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The apparent gap between the measured and the expected value for the semileptonic branching ratio of B mesons has become more serious over the last year. This is due to the improved quality of the data and to the increasing maturity of the theoretical treatment of nonperturbative corrections. We discuss various theoretical options to reduce the semileptonic B branching ratio; among the more spectacular resolutions of the apparent puzzle is the possibility of an unorthodox enhancement in nonperturbative corrections or even of an intervention by “New Physics”. Phenomenological implications of such scenarios are pointed out.

Not included in the theoretical bound:
NNLO corrections to non-leptonic decays.

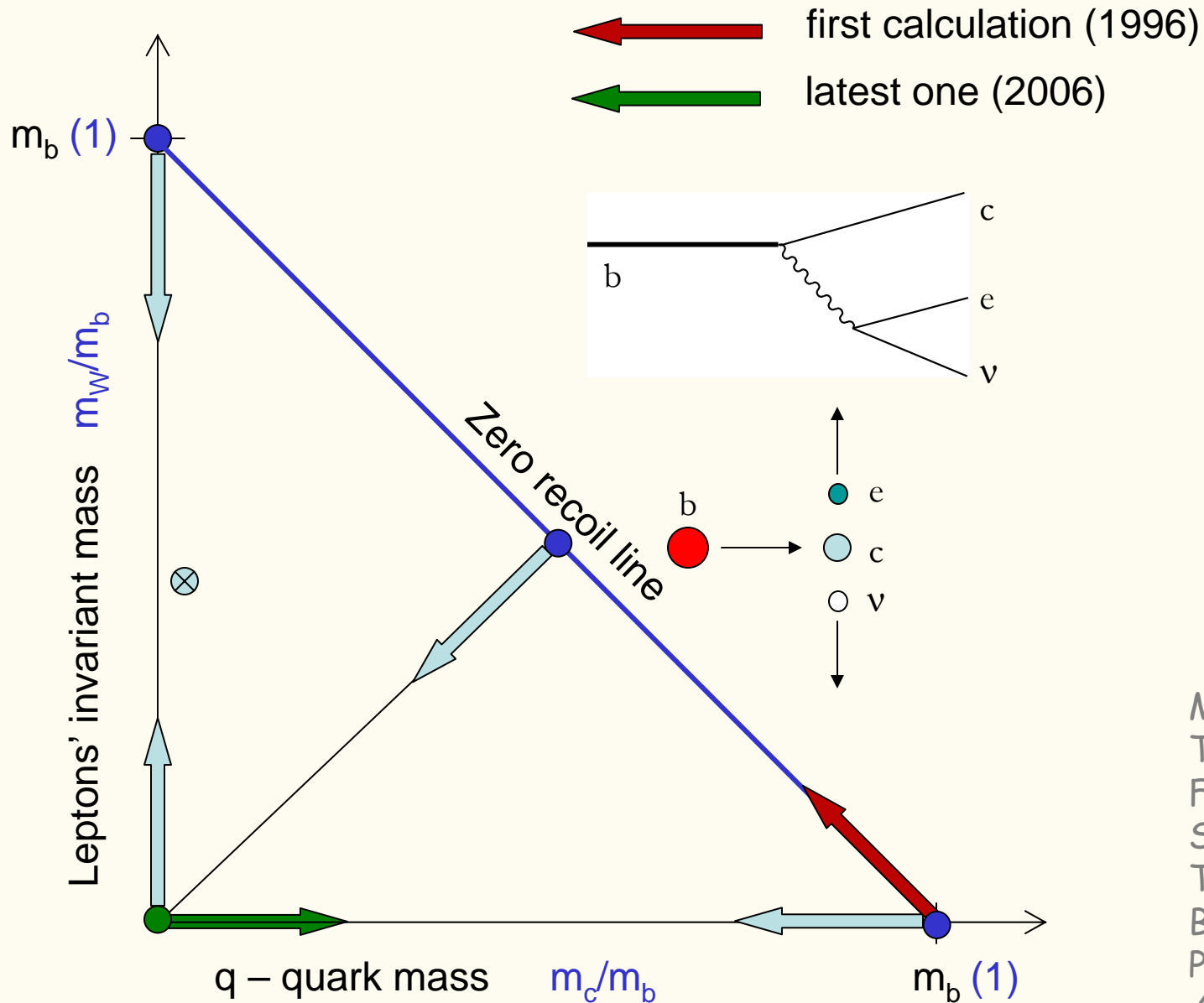
Example:



Four-loop diagrams with masses - tricky (only numerical for $g=2$)

Our approach: reduction via recurrence; analytical determination of "master diagrams"

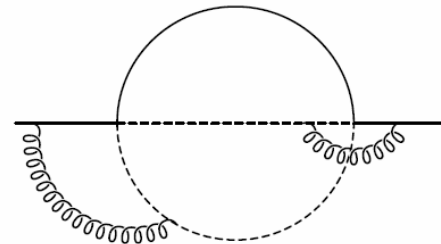
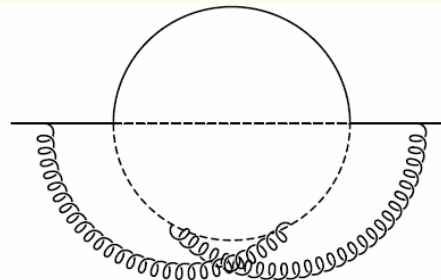
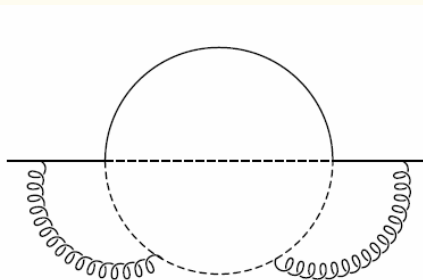
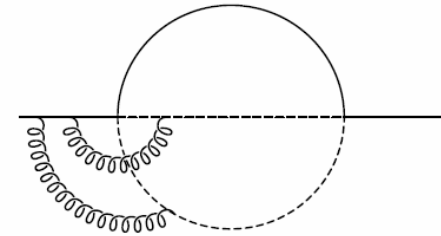
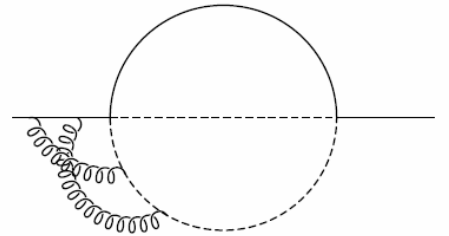
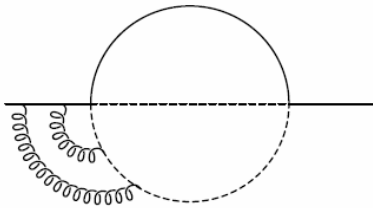
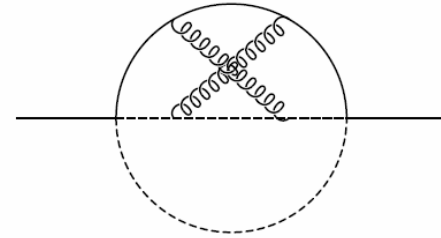
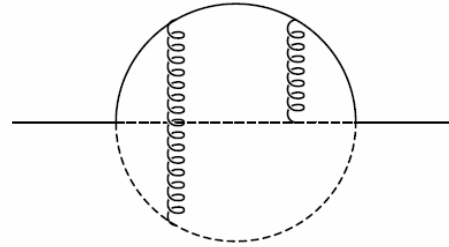
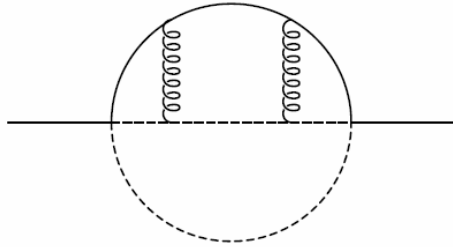
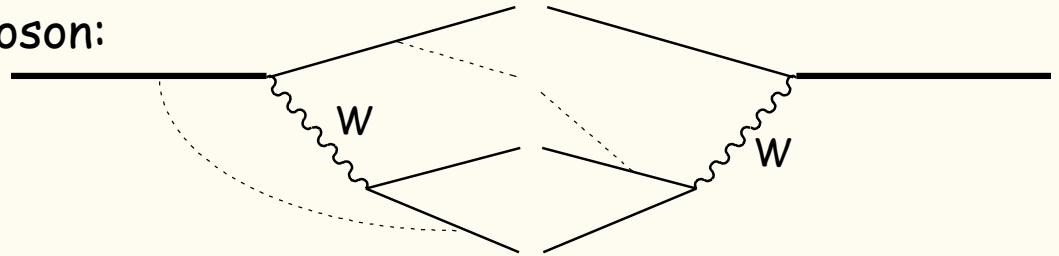
Known two-loop corrections on the bc line



Melnikov,
 Tausk,
 Franzkowski,
 Slusarczyk,
 Tkachov,
 Blokland,
 Pak,
 AC

Additional for hadronic decays: only twelve diagrams

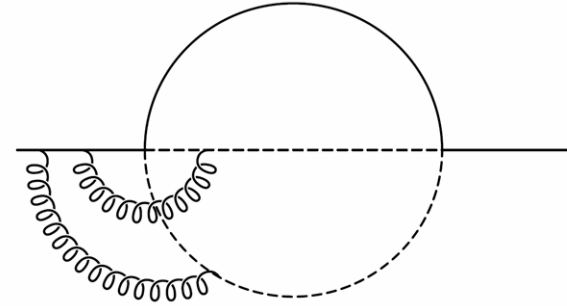
After integrating-out the W boson:



etc.

Results

Example for a single diagram:



$$-\frac{16}{3} \ln^2 \frac{M_W}{m_b} + \left(-\frac{311}{18} + \frac{10}{3} \pi^2 \right) \ln \frac{M_W}{m_b} + \frac{12287}{324} - \frac{143}{162} \pi^2 + \frac{53}{135} \pi^4 - \frac{14}{9} \zeta_3$$

(with Maciek Ślusarczyk)

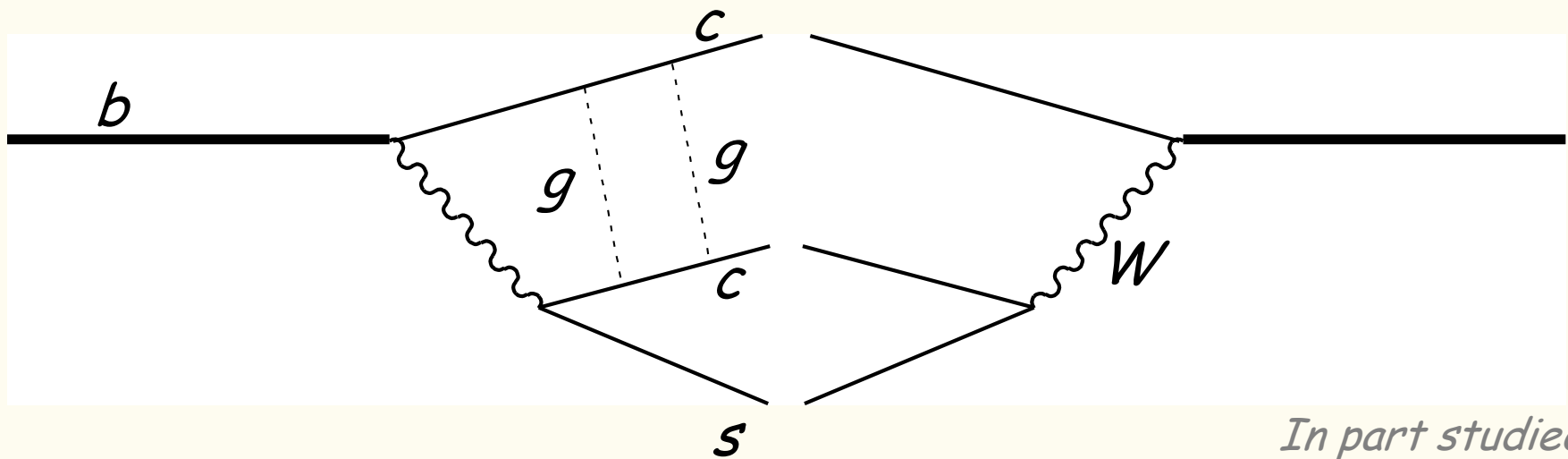
Total correction for the non-leptonic width:

$$\frac{\Gamma(b \rightarrow c\bar{u}d) + \Gamma(b \rightarrow c\bar{u}s)}{3\Gamma(b \rightarrow ce\bar{\nu})} = 1 + \frac{\alpha_s}{\pi} + \left(\frac{\alpha_s}{\pi} \right)^2 \left[4 \ln^2 \frac{M_W}{m_b} + \frac{15}{2} \ln \frac{M_W}{m_b} + 12.4 \right]$$

About 5-8% increase of the NL width;
lowers the theoretical lower bound on B_{SL}

Future: what else is needed to predict the semileptonic/hadronic ratio precisely?

Charm mass effect: possibly very important because of threshold (Coulomb-like) effects:



*In part studied by
Voloshin, 2000*

Summary

"Fair agreement" reached between theory and experiment;

More important: we can further improve the theoretical prediction (account for charm mass);

With new data forthcoming, will we see competitors to W bosons?