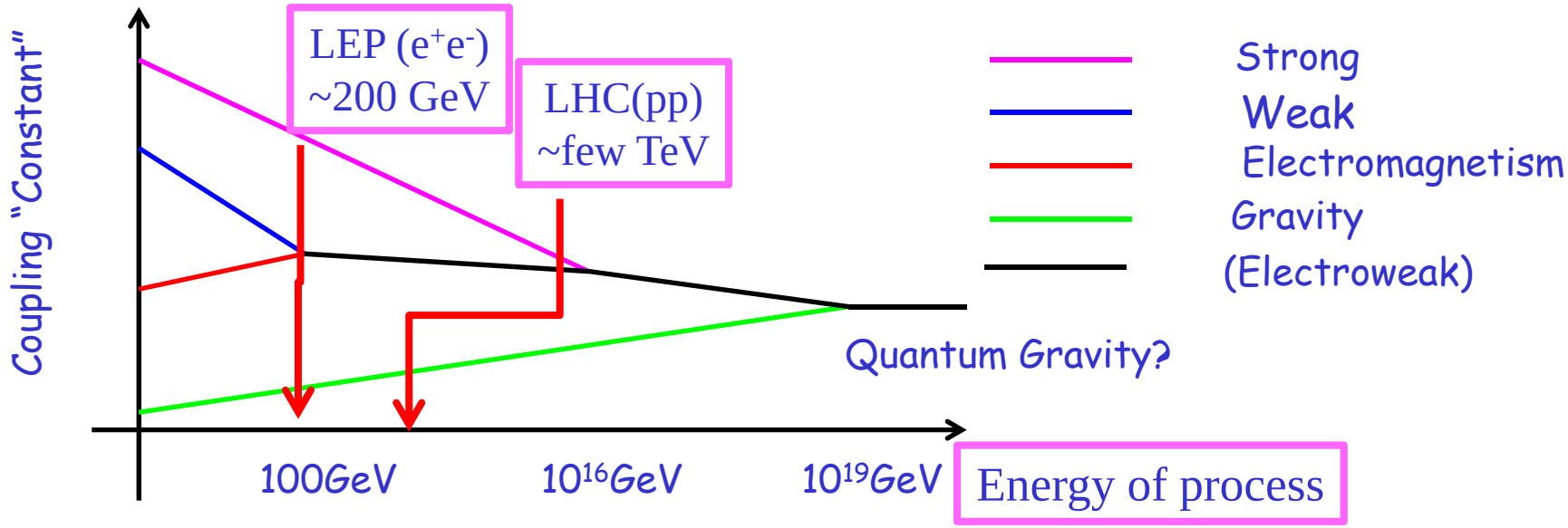
Today (lecture 4)

- (Finish) Electroweak Unification
- Higgs mechanism

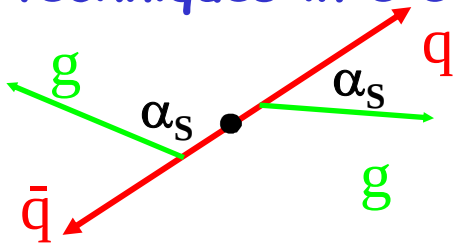
Running Coupling Constants

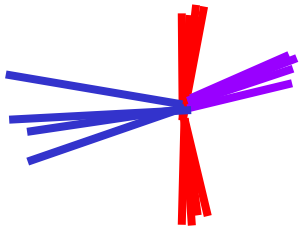
- Coupling "constants" are said to "run" (change their strength) with energy
- For electromagnetism, the coupling "constant", α_{EM}, increased with energy
- For weak force the coupling constant decreases with energy
  - E.M. and weak merge at ~100 GeV: "electroweak unification"
- For strong force coupling, α_s, decreases with energy



Strong Coupling "constant", α_s

- α_s the fundamental, universal QCD parameter
- Standard Model predicts "momentum scale", Q (~√s) evolution, but not absolute value
  - Perturbative effects, varying as ~ 1/lnQ
  - Non-perturbative effects, varying as ~ 1/Q
- Test: measure different processes, energies
- Intuitive techniques in e^+e^-

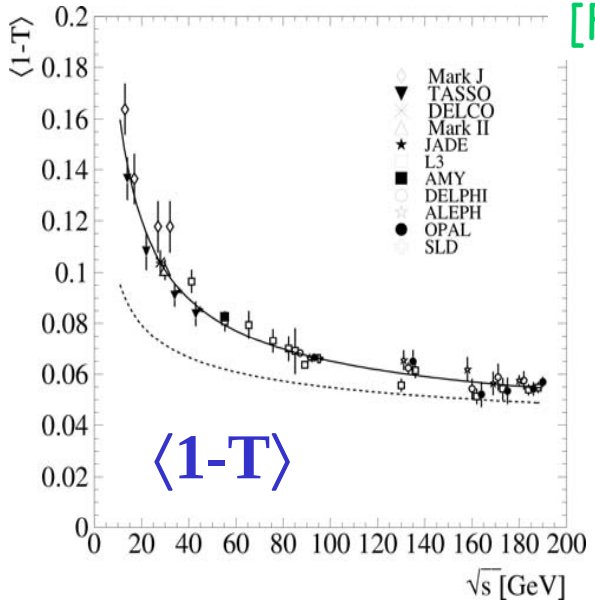


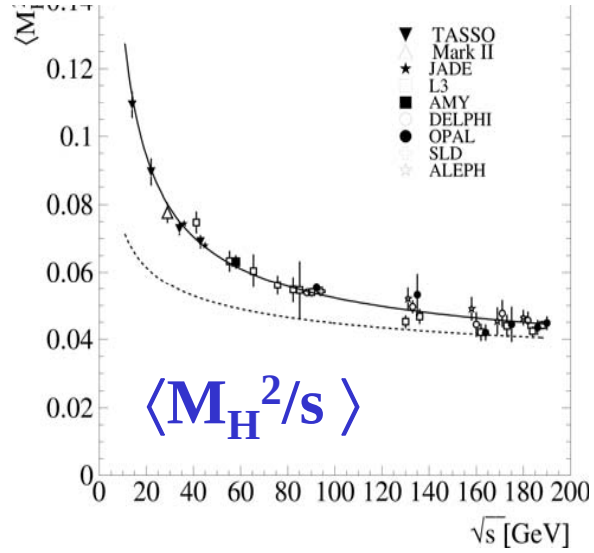


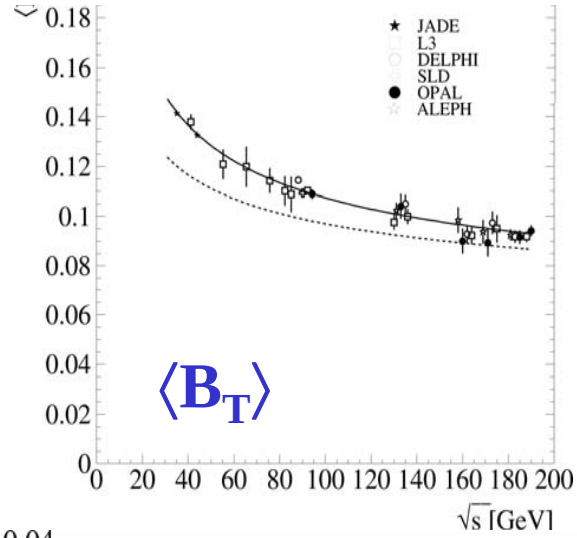
- Precision low, *O*(%) cf. electroweak *O*(10^{-5})

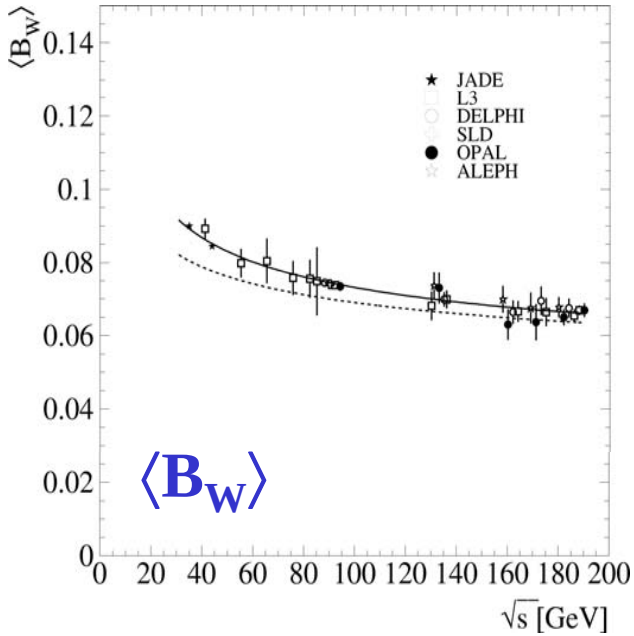
Global α_s measurements, various e^+e^- observables

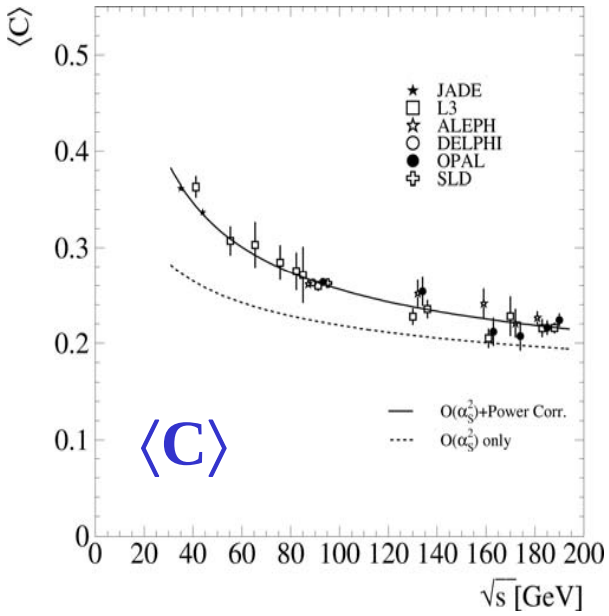
[From P.A. Movilla Fernandez et al., Eur.Phys.J.C22(2001)1]

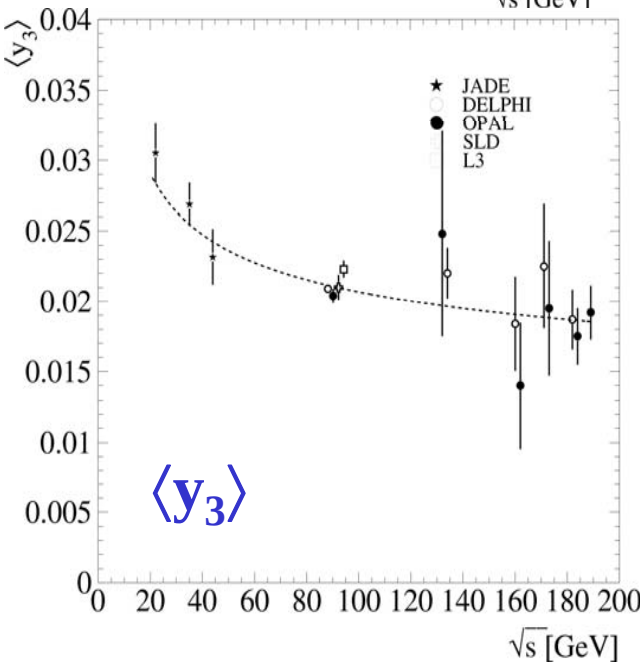




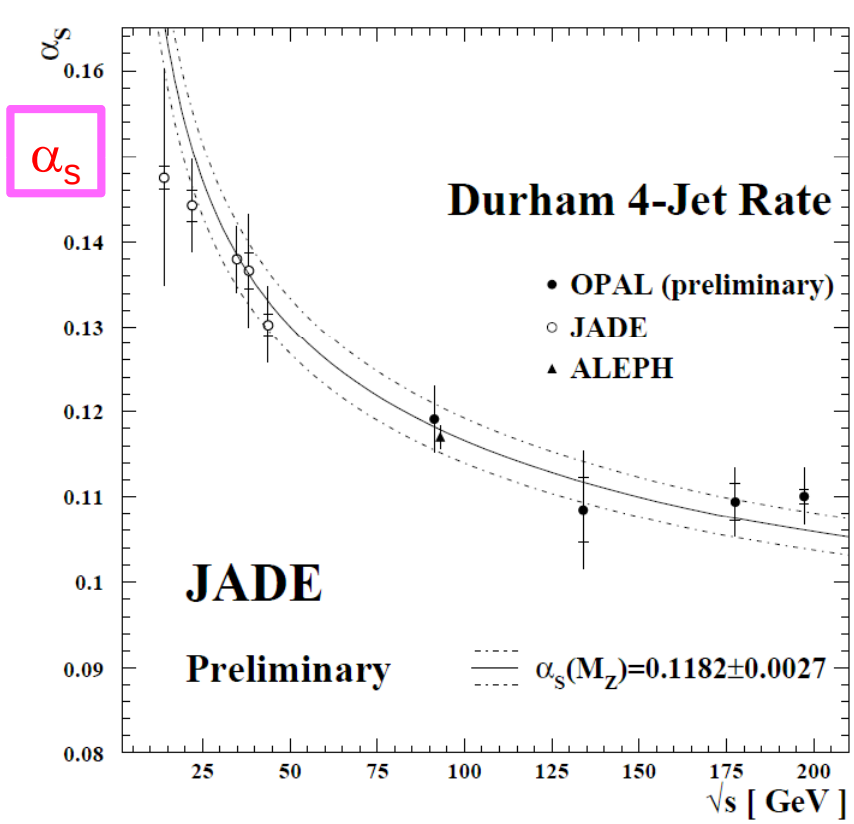


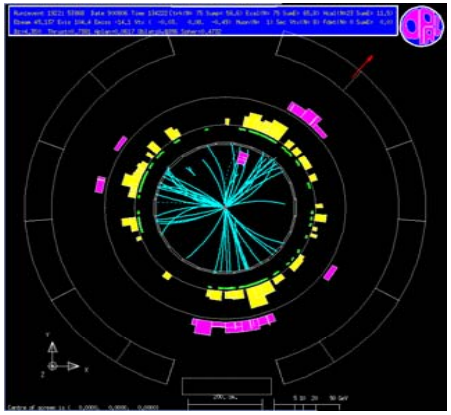






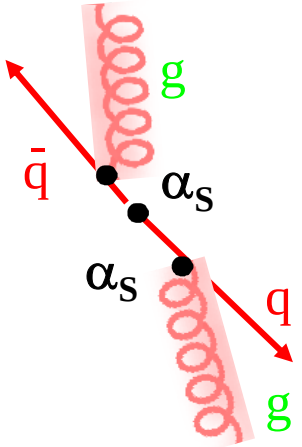
Data: strong coupling constant, α_s



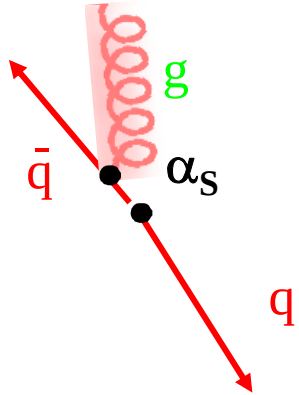


e^+e^- → 3 jets in OPAL detector at LEP (1989-2001)

"parton level" pictures



4-jet event



3-jet event

- α_s is strong force coupling constant
- Ratio of rate of 3-jet vs. 4-jet events
  - Directly related to α_s
  - Analogous to "R", many factors cancel
- Momentum scale-dependent value
  - Centre-of-mass energy in e^+e^- collisions

α_s Summary

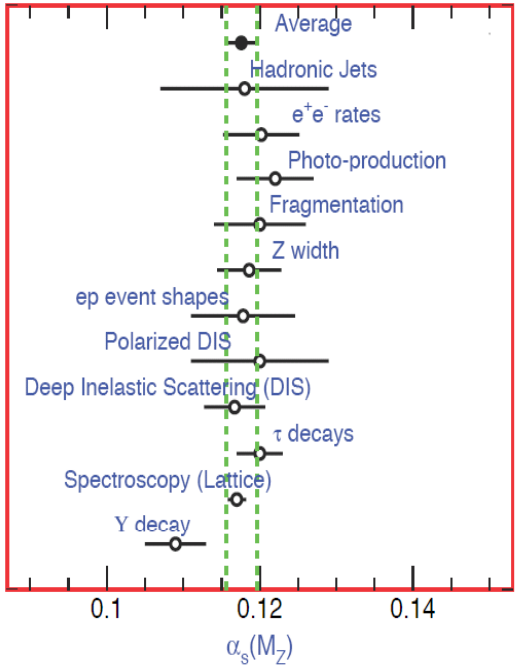


Figure 9.1: Summary of the value of $\alpha_s(M_Z)$ from various processes. The values shown indicate the process and the measured value of α_s extrapolated to $\mu = M_Z$. The error shown is the *total* error including theoretical uncertainties. The average quoted in this report which comes from these measurements is also shown. See text for discussion of errors.

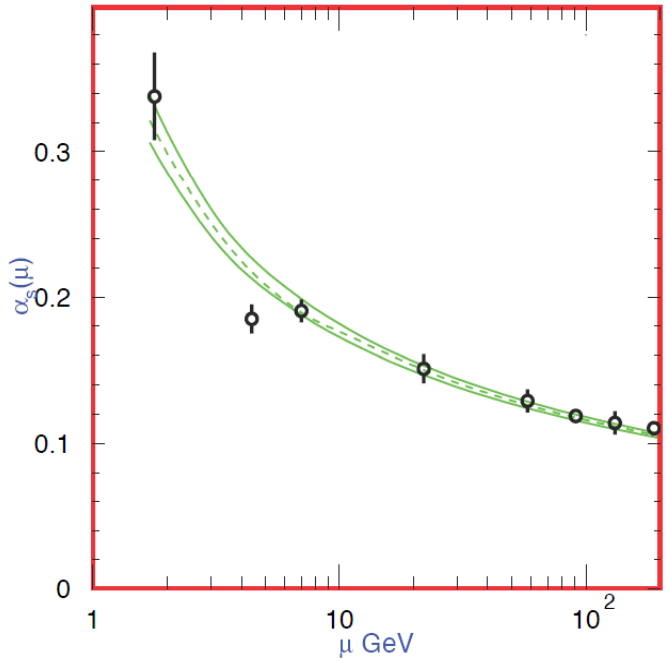


Figure 9.2: Summary of the values of $\alpha_s(\mu)$ at the values of μ where they are measured. The lines show the central values and the $\pm 1\sigma$ limits of our average. The figure clearly shows the decrease in $\alpha_s(\mu)$ with increasing μ. The data are, in increasing order of μ, τ width, Υ decays, deep inelastic scattering, e^+e^- event shapes at 22 GeV from the JADE data, shapes at TRISTAN at 58 GeV, Z width, and e^+e^- event shapes at 135 and 189 GeV.

C. Amsler *et al.*, Physics Letters **B667**, 1 (2008)
[http://pdg.lbl.gov/2008/reviews/rpp2008-rev-qcd.pdf]