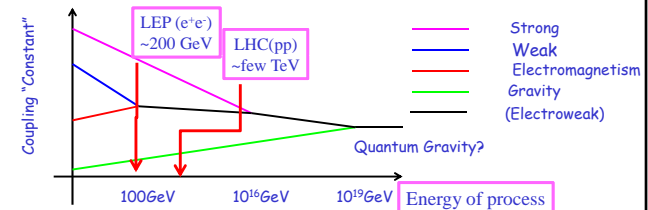


Today (lecture 4)

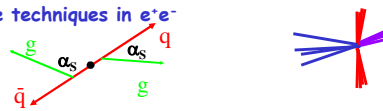
- (Finish) Electroweak Unification
- Higgs mechanism

Running Coupling Constants

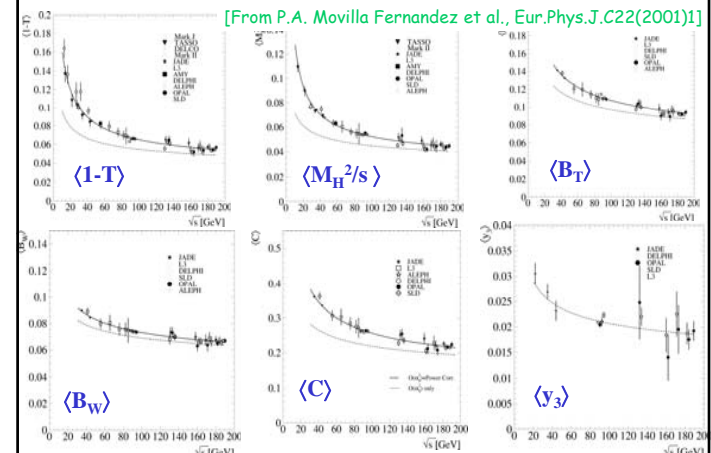
- Coupling "constants" are said to "run" (change their strength) with energy
- For **electromagnetism**, the coupling "constant", α_{EM} , **increased** with energy
- For **weak force** the coupling constant **decreases** with energy
 - ▶ E.M. and weak merge at ~ 100 GeV: "electroweak unification"
-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



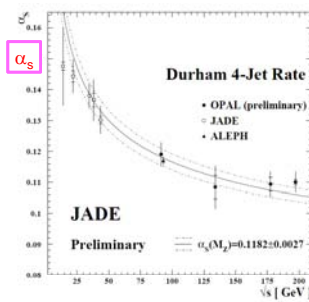
Strong Coupling "constant", α_s

- α_s the fundamental, universal QCD parameter
- Standard Model predicts "momentum scale", Q ($\sim \sqrt{s}$) evolution, but not absolute value
 - ▶ Perturbative effects, varying as $\sim 1/\ln Q$
 - ▶ Non-perturbative effects, varying as $\sim 1/Q$
- Test: measure different processes, energies
- Intuitive techniques in e^+e^-

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

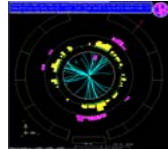
Global α_s measurements, various e^+e^- observables



Data: strong coupling constant, α_s

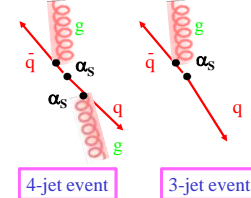


- α_s is strong force coupling constant
- Ratio of rate of 3-jet vs. 4-jet events
 - Directly related to α_s
 - Analogous to "R", many factors cancel
- Momentum scale-dependent value
 - Centre-of-mass energy in e^+e^- collisions



$e^+e^- \rightarrow 3$ jets
in OPAL
detector
at LEP
(1989-2001)

"parton level" pictures



α_s Summary

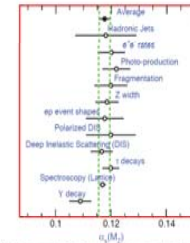


Figure 9.1: Summary of the value of $\alpha_s(M_Z)$ from various processes. The values shown indicate the process and the measured value of α_s extrapolated to $\mu = M_Z$. The error shown is the total error including theoretical uncertainties. The average quoted in this report which comes from these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

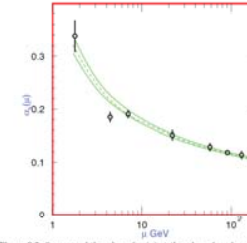


Figure 9.2: Summary of the values of $\alpha_s(p)$ at the values of p where they are measured. The line shows the central values and the $\pm 1\sigma$ limits of our average. The figure clearly shows the decrease in $\alpha_s(p)$ with increasing p . The data sets, in increasing order of p , are: e^+e^- width, Z decays, deep inelastic scattering, e^+e^- event shapes at 22 GeV from the JADE data, shapes at TRISTAN at 59 GeV, Z width, and e^+e^- event shapes at 130 and 189 GeV.

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