4442 Particle Physics
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Week 6

http://www.hep.ucl.ac.uk/~markl/teaching/4442

Week 6

We've now developed a theory that incorporates all the necessities to make it useful ie predictive and amenable to falsification or validation by experiment.

We've incorporated :

- Lorentz invariance (+ Special Relativity)
- Quantum Mechanics, Spin and anti-particles (Dirac Eqn)
- Gauge invariance (No dependence on "un-measurables")
- Interactions and a tractable formalism (Lagrangians**)

The full formalism in Quantum Field Theory as embodied in the Standard Model has been subject to thousands of measurements + never been found wrong.

But in the words of D. Rumsfeld we know there are "known unknowns".

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Validation of the spin 1/2 interacting gauge theories of QED(+weak) and QCD.

- Angular distributions in ee → μμ, eμ → eμ, eq → eq scattering
  - The importance of spin, and helicity conservation
  - Interference amplitudes, A_{FB}

- Demonstration of quark properties
  - spin 1/2
  - fractional charge
  - carry colour

- Derivation of cross section formula for $e^+e^- \to \mu^+\mu^-$, $e^-\mu^- \to e^-\mu^-$ (**)
- Correspondence between helicity and chiral operators
- No chirality/handedness changing processes occur in any pure vector ie QCD + QED or axial vector interactions

$$\sigma(e^+e^- \to qq) \text{ vs } \sqrt{s} \ (\text{GeV})$$
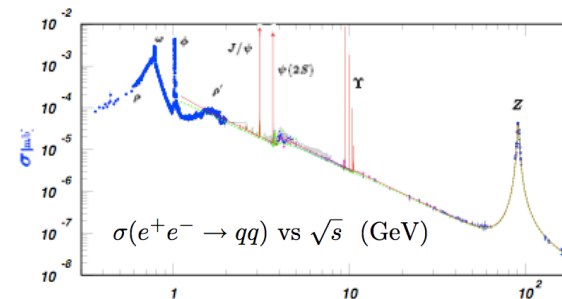
$$\sigma(e^+e^- \to \mu^+\mu^-) = \frac{4\pi\alpha^2}{3s} = \frac{87.0}{s} \text{ nb}; \quad \text{s in GeV}^2$$

$$\frac{d\sigma}{d\Omega}(e^+e^- \to \mu^+\mu^-) = \frac{\alpha^2}{4s}\left(1 + \cos^2\theta\right)$$

QED+QCD angular distribution is symmetric due to chirality (aka helicity at high energy) and hence parity conservation of vector interactions and because we have a spin=1 boson being exchanged

Deviation from pure QED expectation is due to interference terms from Z exchange at level of ~ 10^{-4} s ***

Forward-backward asymmetries : A_{FB} ** ;
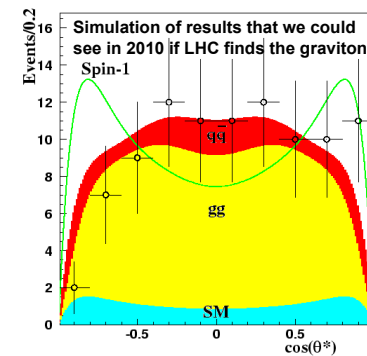 $e^+e^- \to e^+e^-$ difference & HO corrections
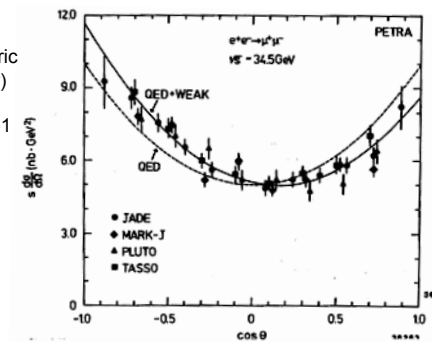
Angular distributions are used to determine spins of interacting & exchanged particles

- evidence that quarks are spin 1/2 (see later)
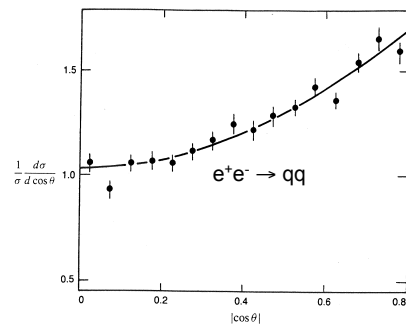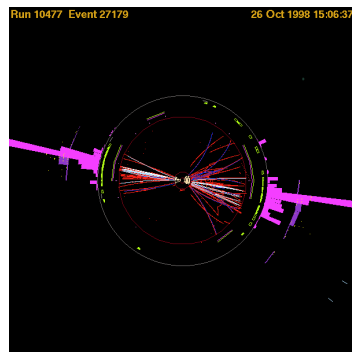- search for new physics e.g. demonstrate that spin of mythical graviton = 2 not 1

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Evidence Quark Properties
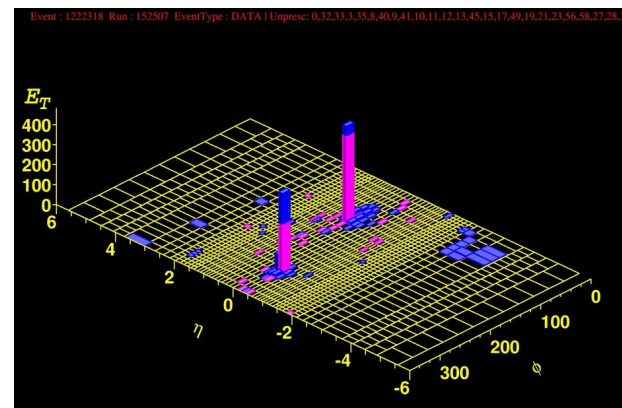
- spin 1/2 : angular distribution of quark jets in $e^+e^- \to qq$ or $eq \to eq$
- fractionally charged
- carry color

Run 10477 Event 27179   26 Oct 1998 15:06:37

$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta}$ $e^+e^- \to qq$

$|\cos\theta|$

World's Highest energy collision at CDF/Fermilab : producing 2 jets of invariant mass = 1100 GeV : what is this in distance ?

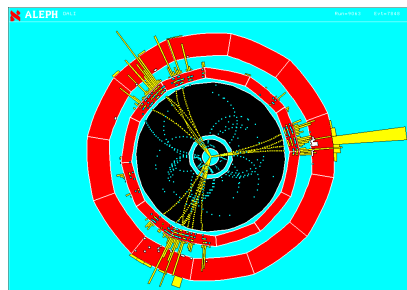Event : 1222318 Run : 152507 EventType : DATA | Unpresc: 0,32,33,3,35,8,40,9,41,10,11,12,13,45,15,17,49,19,21,23,56,58,27,28,30,
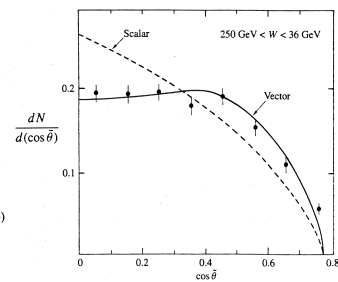
E_T

η

ϕ

4

Evidence that gluon is spin = 1 ie vector not a scalar (spin = 0) particle
 - measure 3 jet events and angle of highest energy jet with respect to axis defined
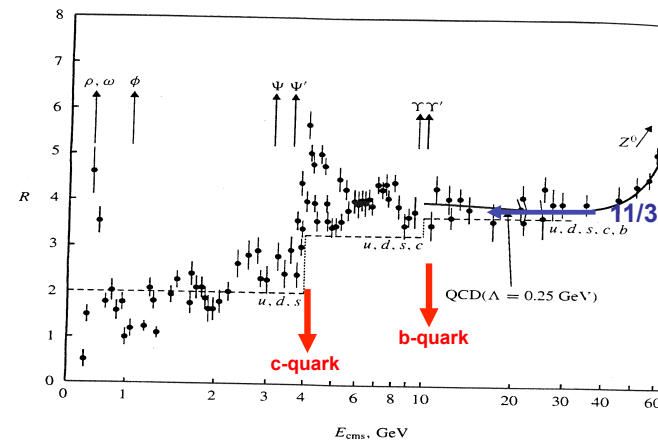   by the other 2 jets

Evidence that quarks are fractionally charged
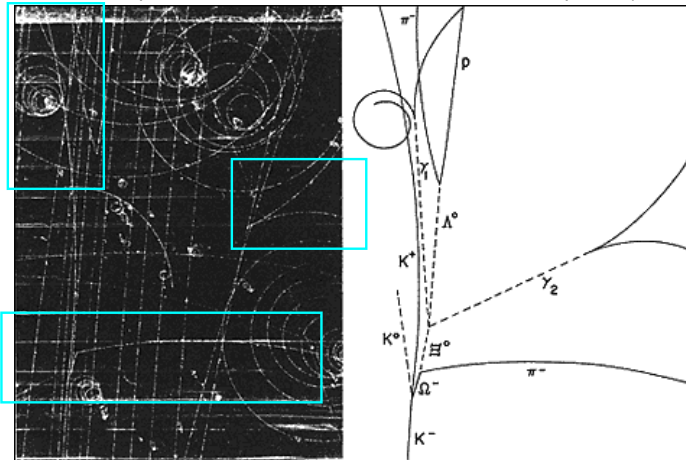 - R; ratio of proton to neutron magnetic moment; charges of baryons e.g. Δ^{++}

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Evidence that quarks carry color
 - existence of Ω^- particle ; R has factor of 3; there are no free quarks (confinement)

Three quarks for Muster Mark!
Sure he hasn't got much of a bark
And sure any he has it's all beside the mark.

Sir Tristram, violer d'amores, fr'over the short sea, had passen-
core rearrived from North Armorica on this side the scraggy
        isthmus of Europe Minor to wielderfight his penisolate war: nor
        had topsawyer's rocks by the stream Oconee
exaggerated themselse to Laurens County's gorgios while they
went doublin their mumper all the time: nor avoice from afire
bellowsed mishe mishe to tauftauf thuartpeatrick: not yet,
though venissoon after, had a kidscad buttended a bland old
isaac: not yet, though all's fair in vanessy, were sosie sesthers
wroth with twone nathandjoe. Rot a peck of pa's malt had
Jhem or Shen brewed by arclight and rory end to the
regginbrow was to be seen ringsome on the aquaface.

 The fall (bababadalgharaghtakamminarronnkonnbronntonner-
ronntuonnthunntrovarrhounawnskawntoohoohoordenenthur-
nuk!) of a once wallstrait oldparr is retaled early in bed and
later on life down through all christian minstrelsy.

Deep Inelastic Scattering (DIS) : The quark & gluon structure of the proton

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