Particle discoveries; 2

Overview

- Discovery of fundamental particles in the last 100 years
- See how possibility of discovery goes hand in hand with available energy and technology

This lecture:

Fundamental particles from 1970 onwards

Completion of second family

Third family

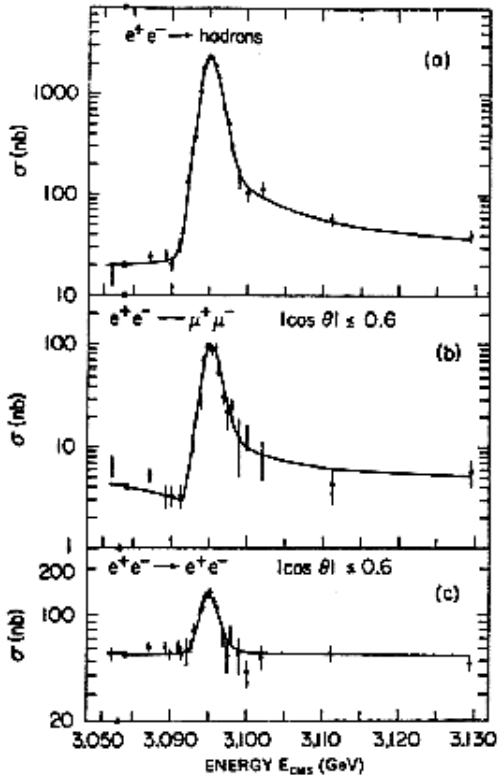
Is there anything left to discover?

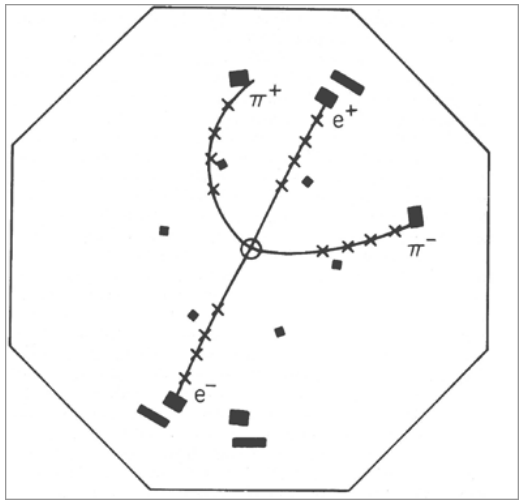
Charm: J/ψ ($c\bar{c}$) meson (1974)

SLAC linac; variable cm energy

$e^+e^- \rightarrow X$;

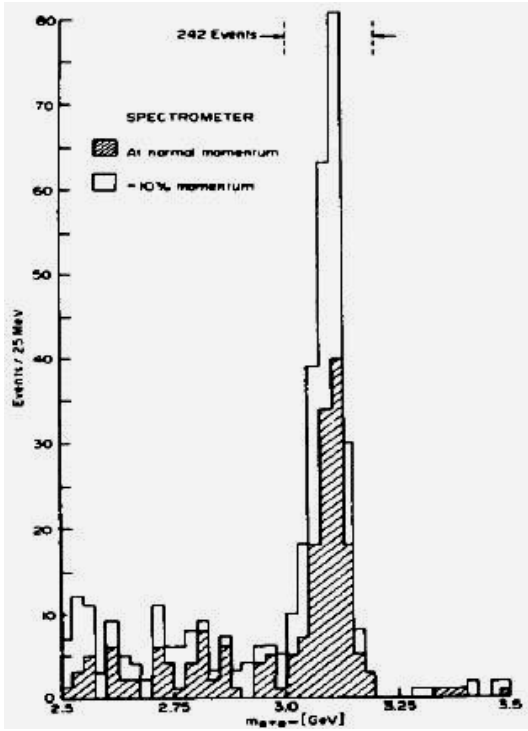
cross-section increases at J/Ψ mass





$\Psi'(3700) \rightarrow J/\psi\ \pi^+\pi^-$

$J/\psi \rightarrow e^+e^-$

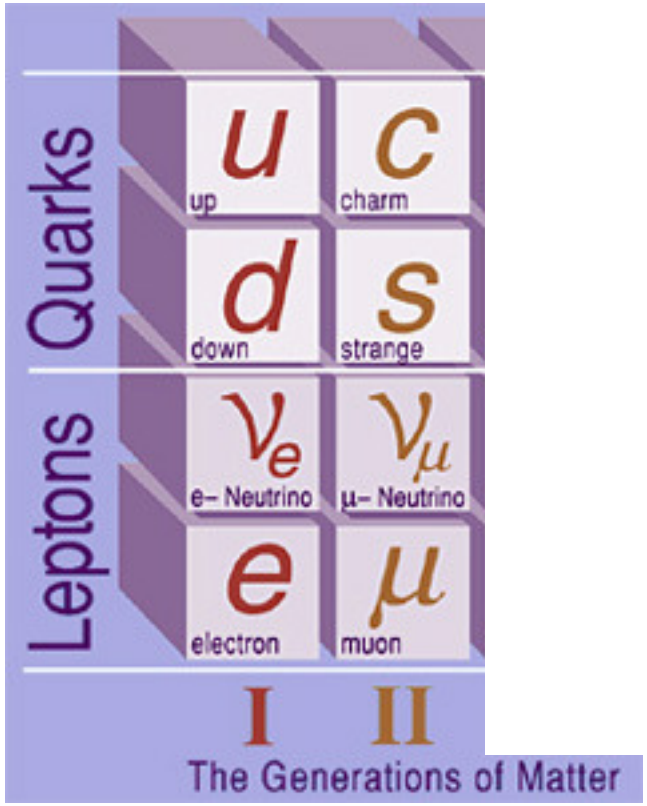


Brookhaven: fixed target

$p+Be \rightarrow J/\psi + X$

(direct reconstruction of mass)

Second generation completed



Bosons: gluon

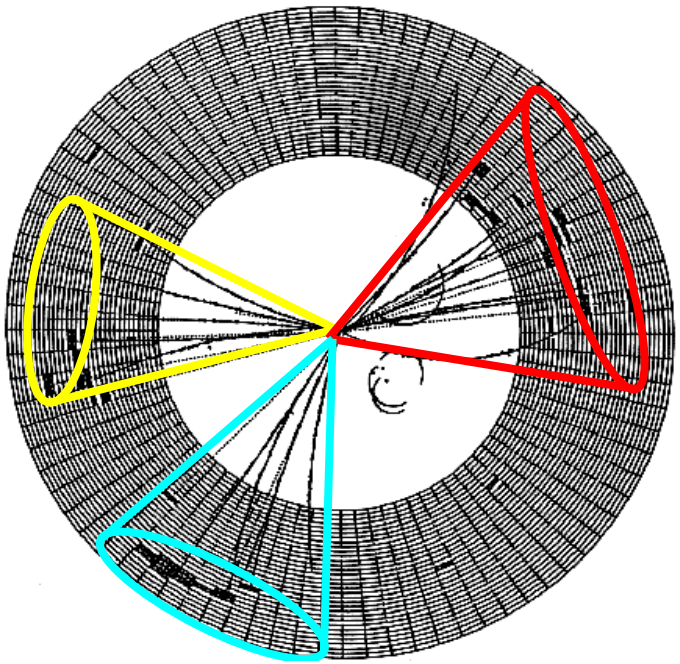
Gluon – mediator of STRONG FORCE

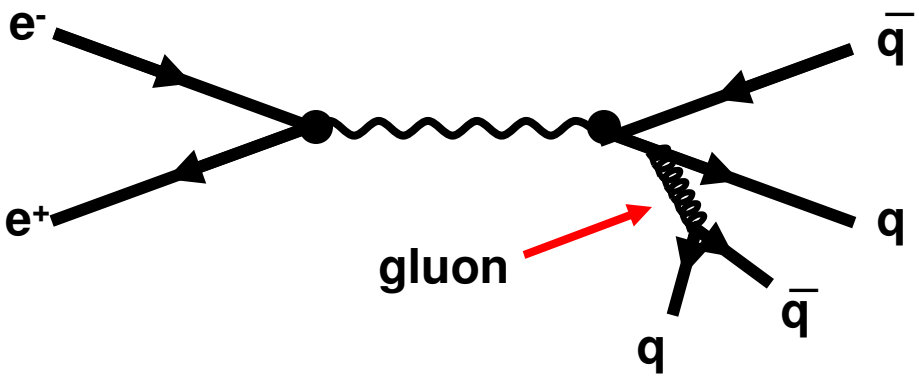
1979: PETRA e^+e^- collider, Hamburg

CM energy ~ 30 GeV

$e^+e^- \rightarrow q + \bar{q} + g\ (g \rightarrow q\bar{q})$

Gluon fragments: 3 jets in detector



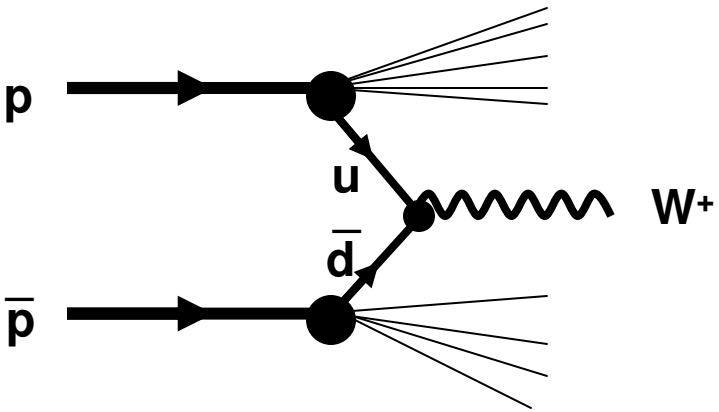


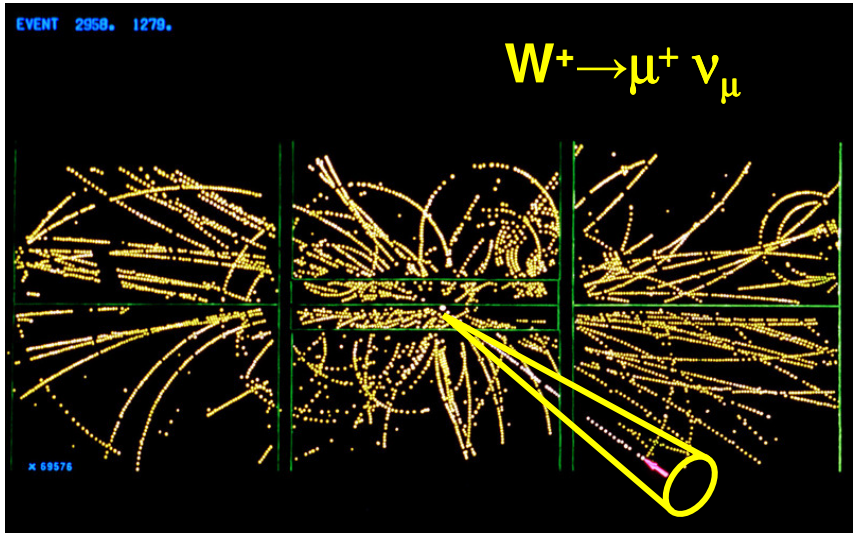
Bosons; W, Z

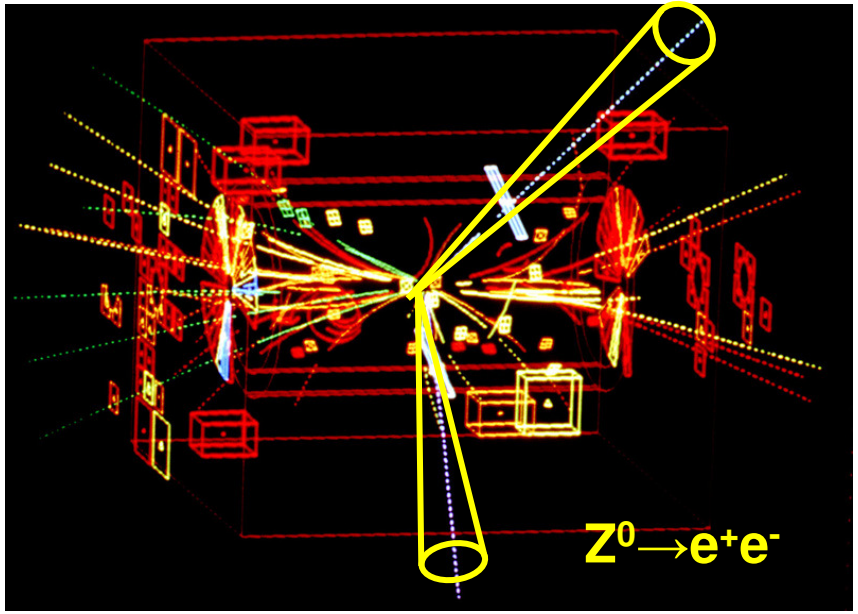
W,Z carriers of WEAK FORCE

1983 UA1, UA2 experiments, SPS CERN

$p\bar{p}$ collider cm energy $\sqrt{s}$=540 GeV



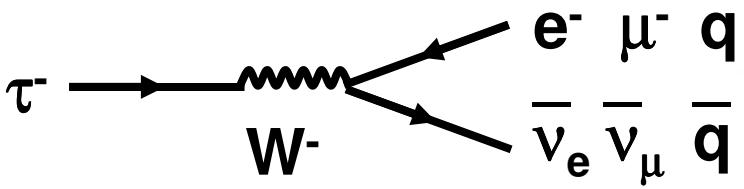


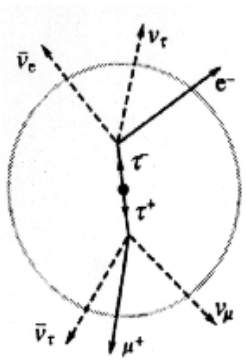


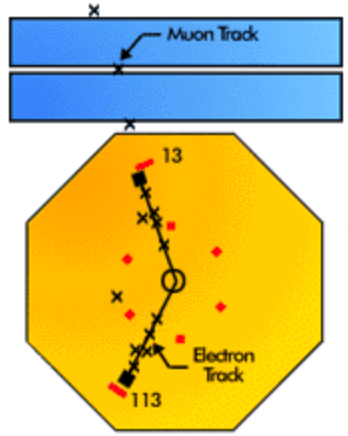
3rd generation leptons: τ, ντ

Tau: 1975

SLAC linac. $e^+e^- \rightarrow \tau^+\tau^-$



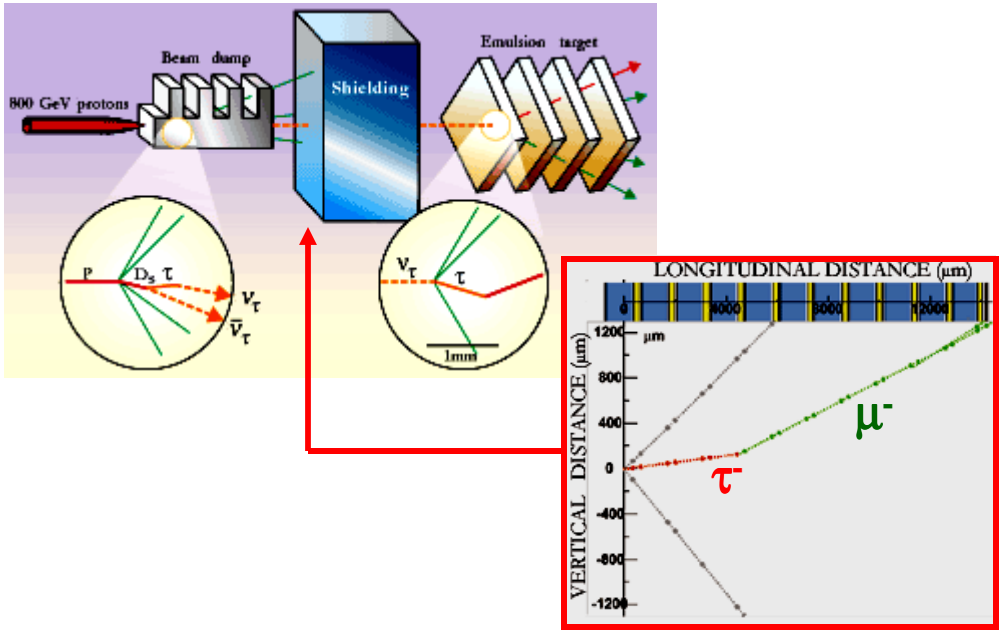




Tau neutrino: 2000

DONUT experiment, Fermilab

800 GeV proton beam on Tungsten target



Bottom

1977:

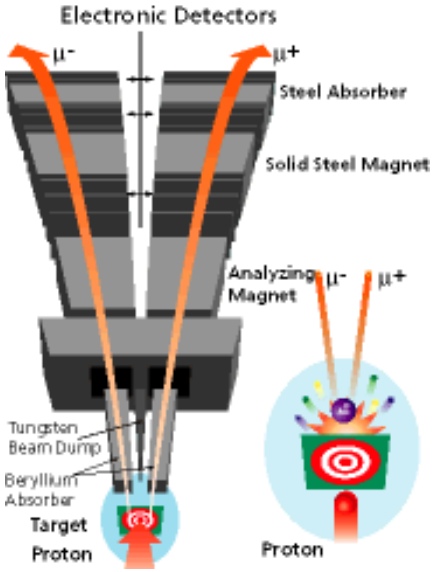
Fermilab. Fixed target experiment

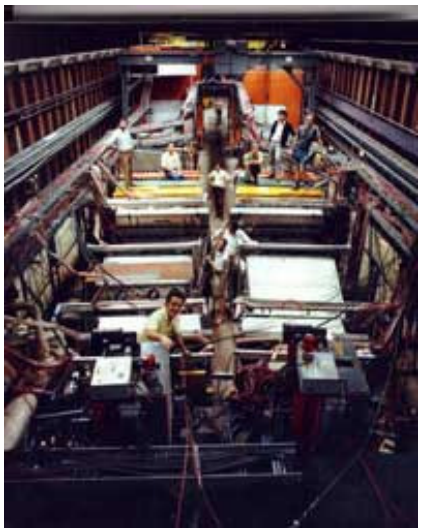
Detects muon pairs

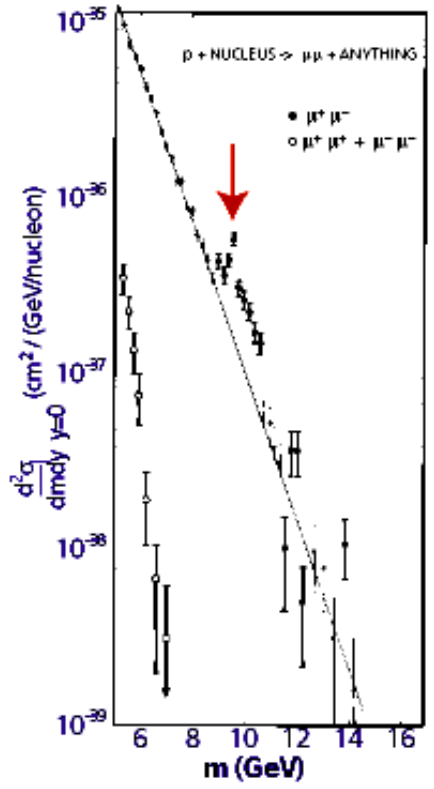
P+Tungsten→(b$\bar{b}$) + anything

b→c μ ν_μ

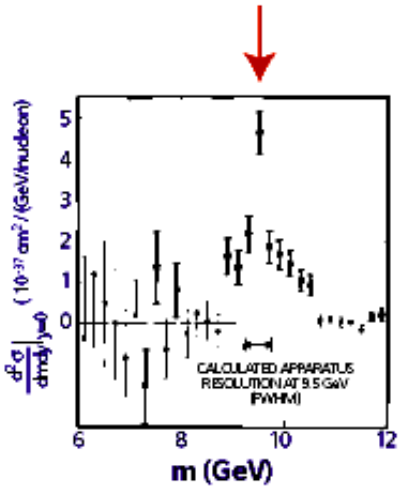
b→c μ ν_μ







Results published in Physical Review Letters August 1, 1977



Increase in cross-section around Ψ mass (like J/ψ)

Top

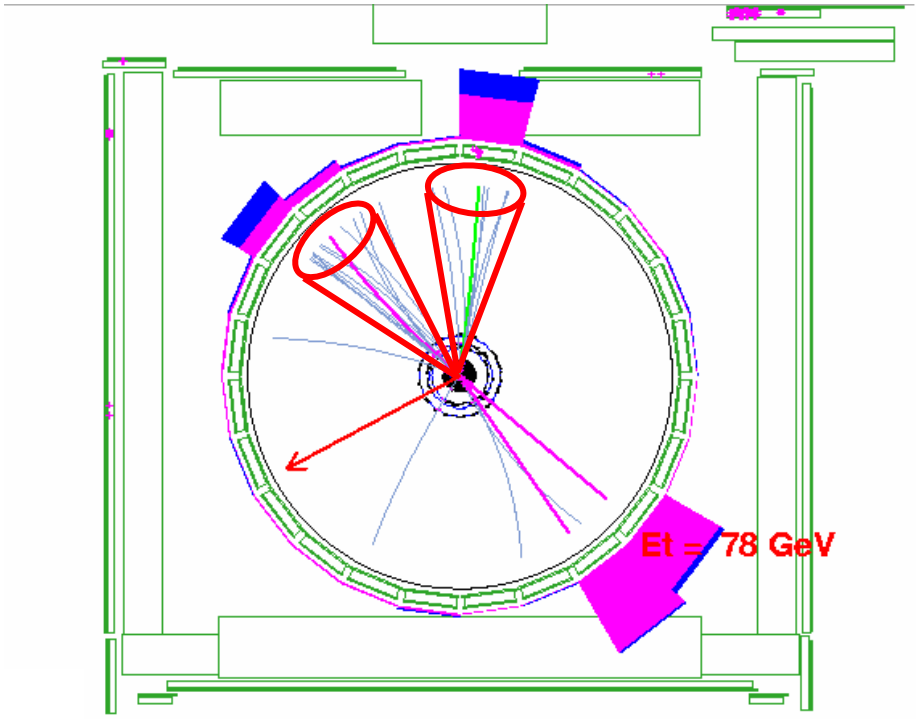
1994: Fermilab Tevatron

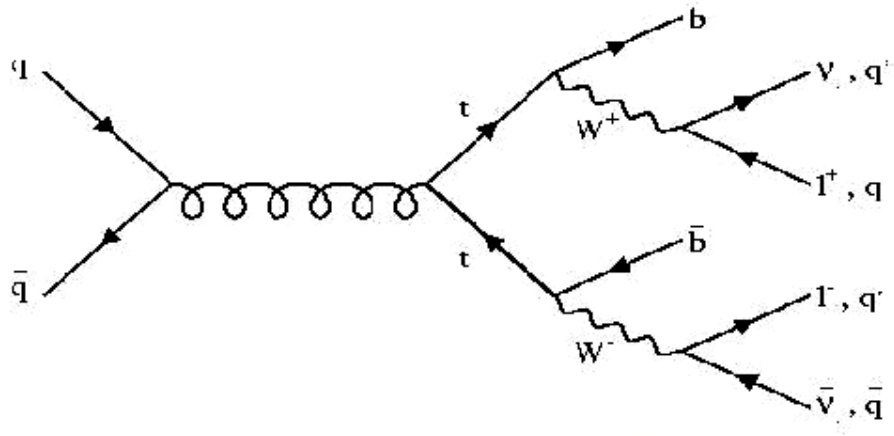
$p\bar{p}$ collider cm energy = 1.8 TeV

Top antitop pairs produced

Top decays instaneously to W + b (usually)

- See jets and/or leptons as signature





$t \rightarrow e^+ \nu_e b$

$\bar{t} \rightarrow e^- \bar{\nu}_e \bar{b}$

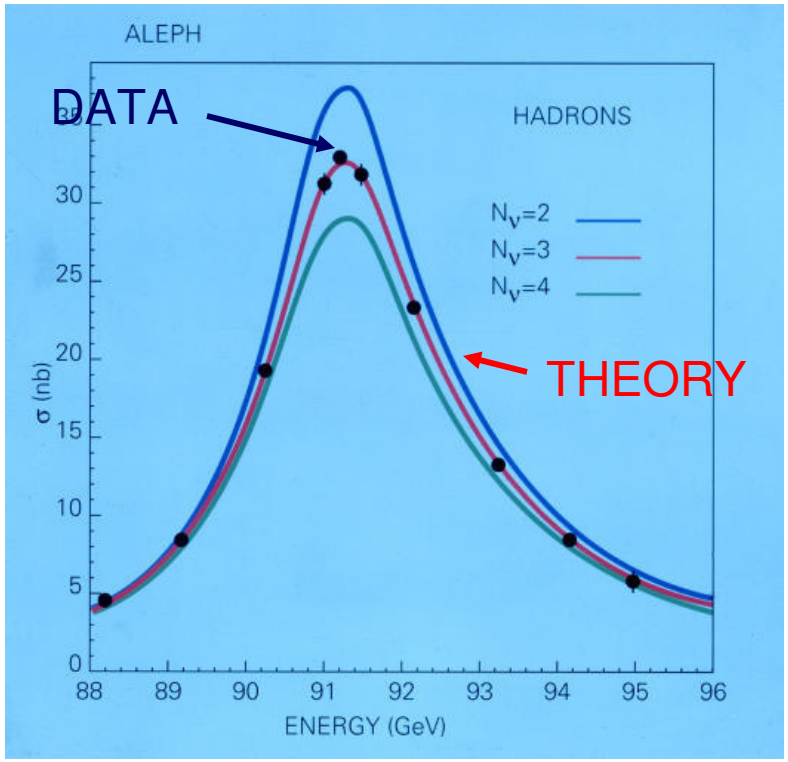
Any more generations?

Can find no. families INDIRECTLY

Use LEP data (e^+e^- collider, cm=mass of Z boson)

Z decays to $p\bar{p}$ (p=lepton,quark)

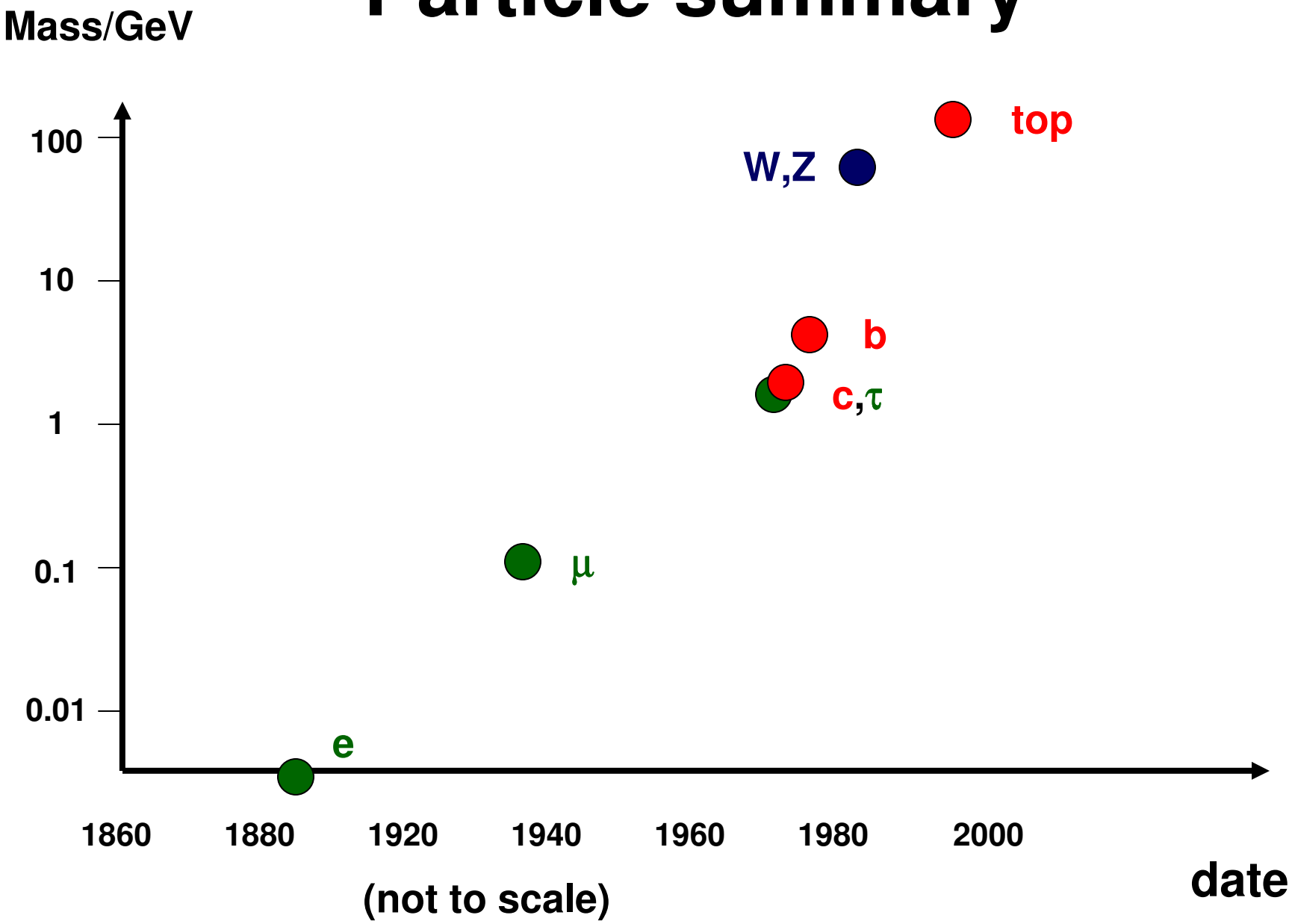
Probability of decay α no. possible decays (measured by Γ)



Particle summary

photon	1923	Compton scattering
gluon	1979	e^+e^- collider
W, Z	1983	pp collider
e	1898	Cathode tube
μ	1947	Cosmic rays
τ	1975	e^+e^- linac
neutrino	1956	Nuclear reactor
u,d,s	1962	π, K seen in cosmic rays earlier
c	1974	e^+e^- linac, fixed target proton beam
b	1977	Fixed target proton beam
t quark	1994	pp collider

Particle summary



Any more particles?

Expected by SM:

- Higgs
  - Can detect indirectly through loop contributions
  - Alters theoretical predictions as fn. M(H)
  - Compare to data to fit m(H)
  - Currently, m(H)>115 GeV/c^2

Not expected by SM:

- Up to your imagination!
- SUSY: links fermions and bosons ("superpartners")
- Technicolor, Large extra dimensions, leptoquarks ……

Review

Discovery of known fundamental particles outlined:

- Discoveries echo technology
- First discoveries used cathode tubes
- Then cosmic rays
- Then accelerators
- As more CM energy available, more particles found