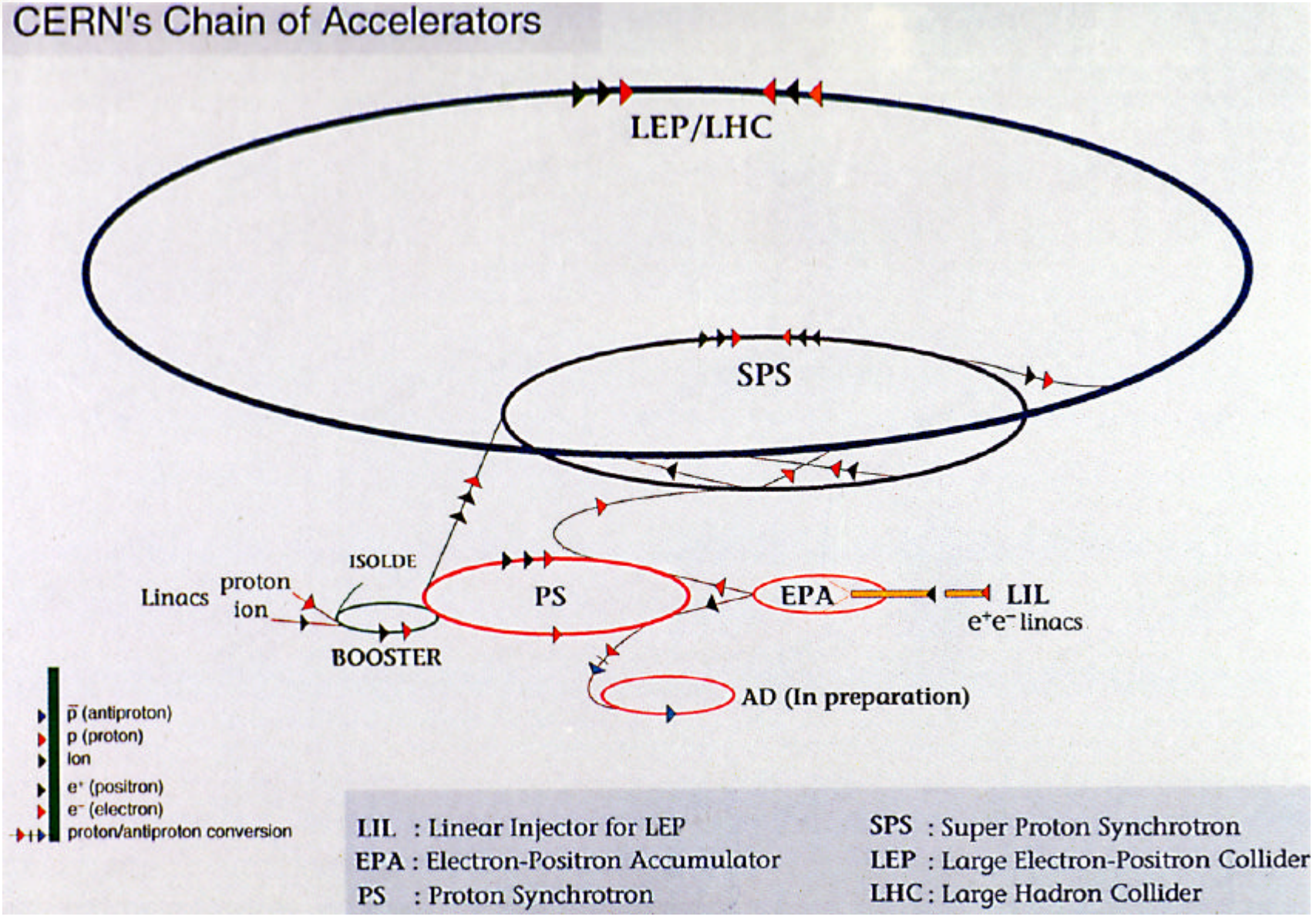
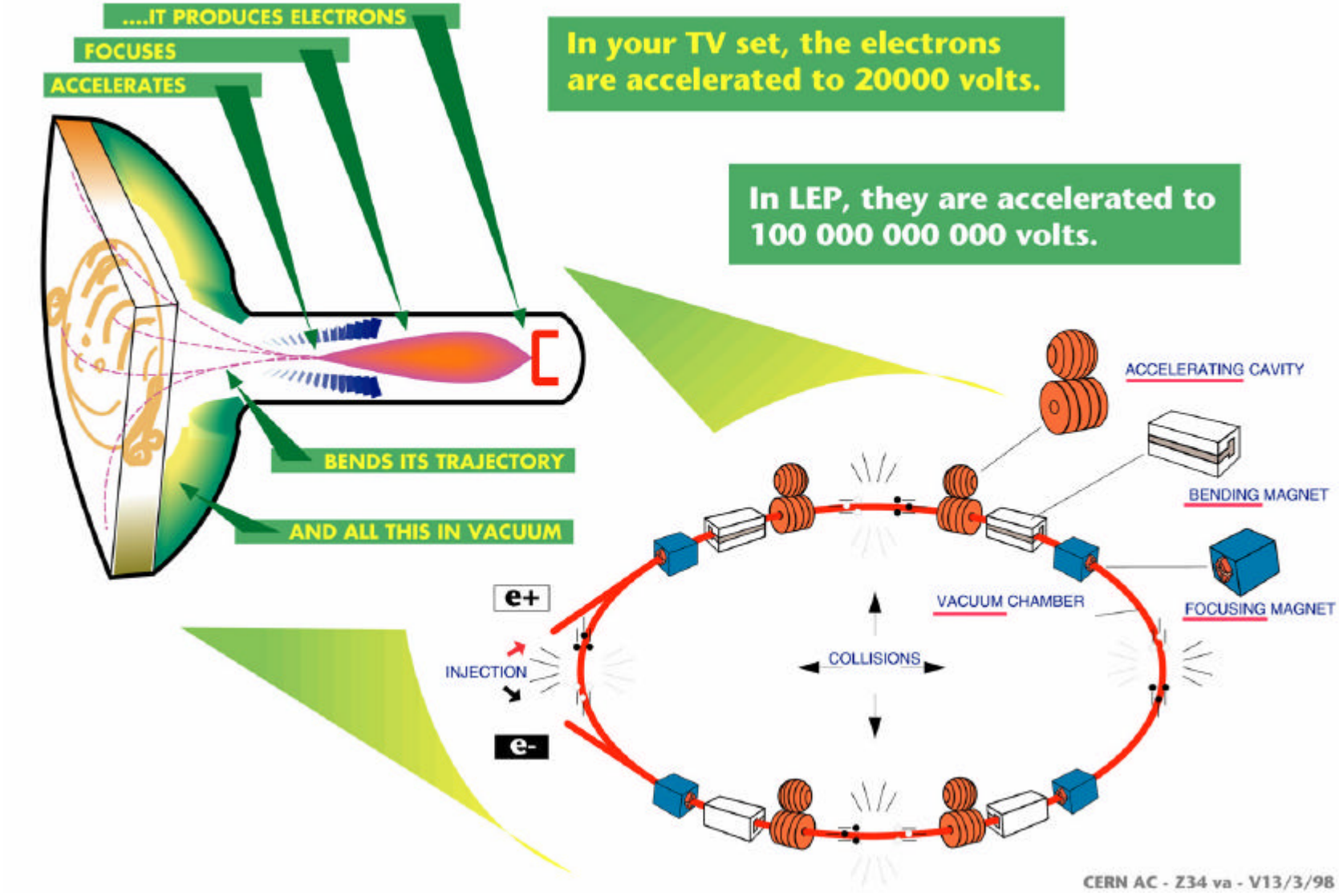
The CERN Accelerator Complex

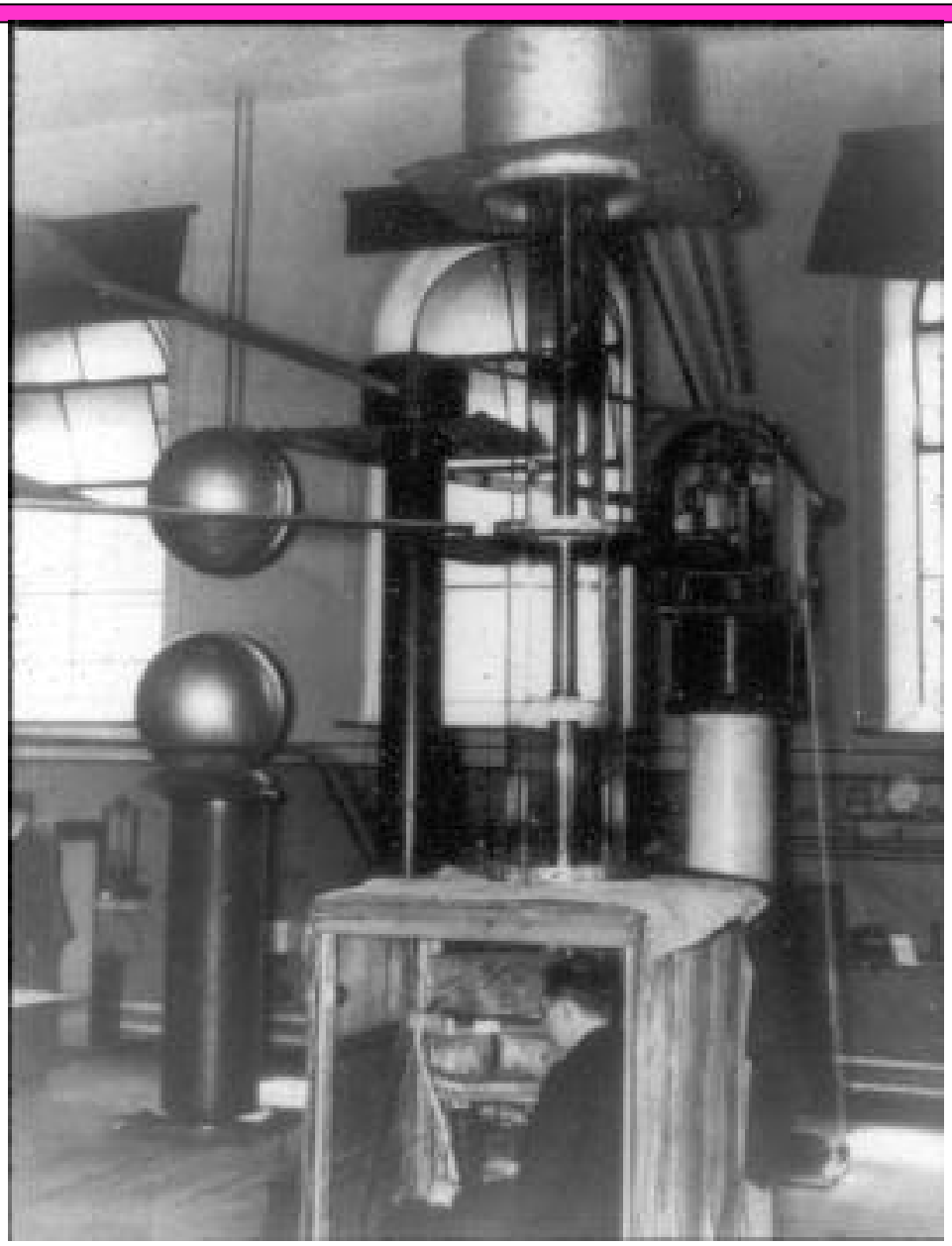
A View of the LEP Tunnel


CERN's Chain of Accelerators
LEP/LHC
SPS
ISOLDE
Linacs
proton
ion
PS
EPA
LIL
e+e− linacs
BOOSTER
AD (In preparation)
p̄ (antiproton)
p (proton)
ion
e+ (positron)
e− (electron)
proton/antiproton conversion
LIL : Linear Injector for LEP
EPA : Electron-Positron Accumulator
PS : Proton Synchrotron
SPS : Super Proton Synchrotron
LEP : Large Electron-Positron Collider
LHC : Large Hadron Collider

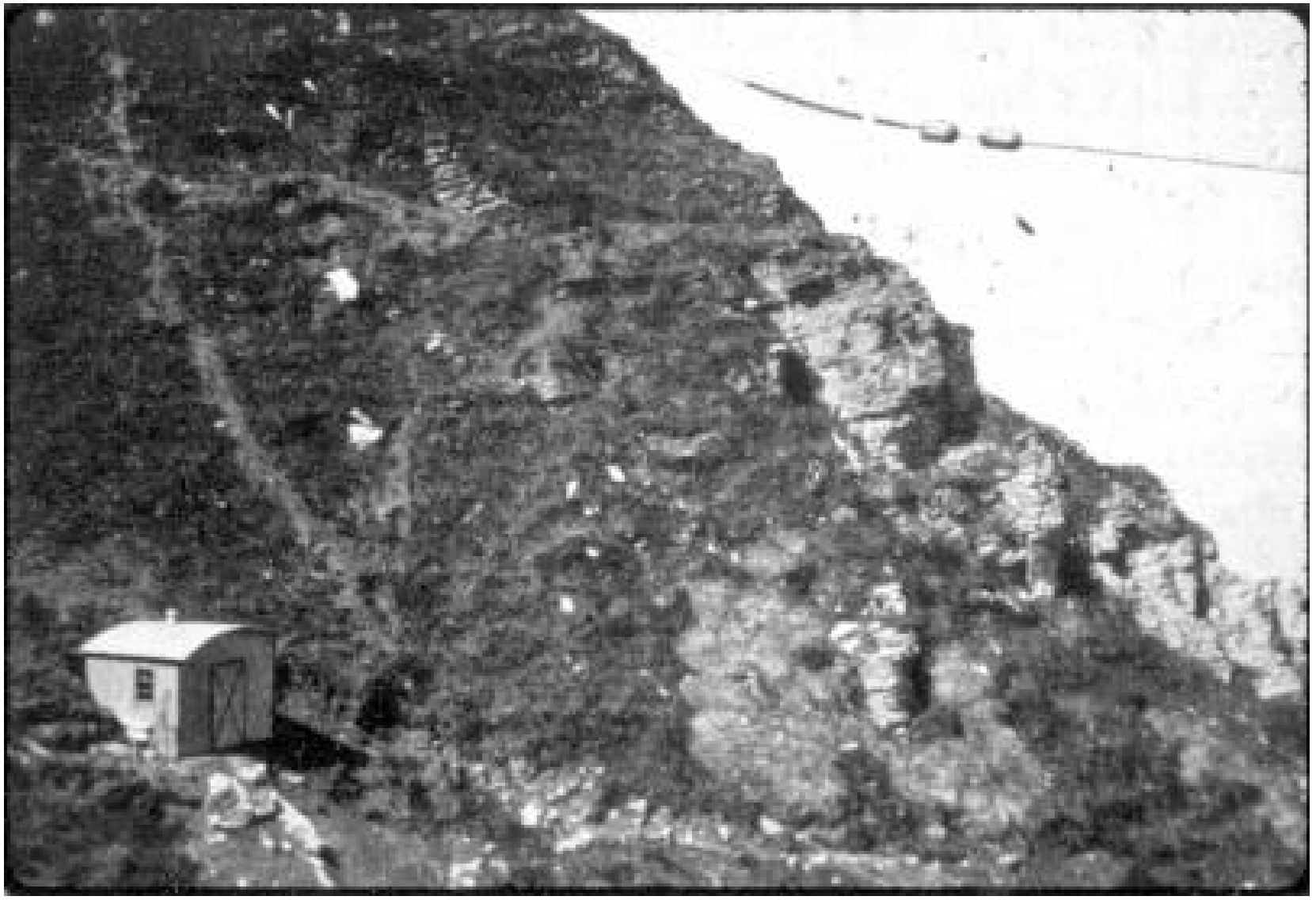
CERN Provides a Wealth of Instructional Aids



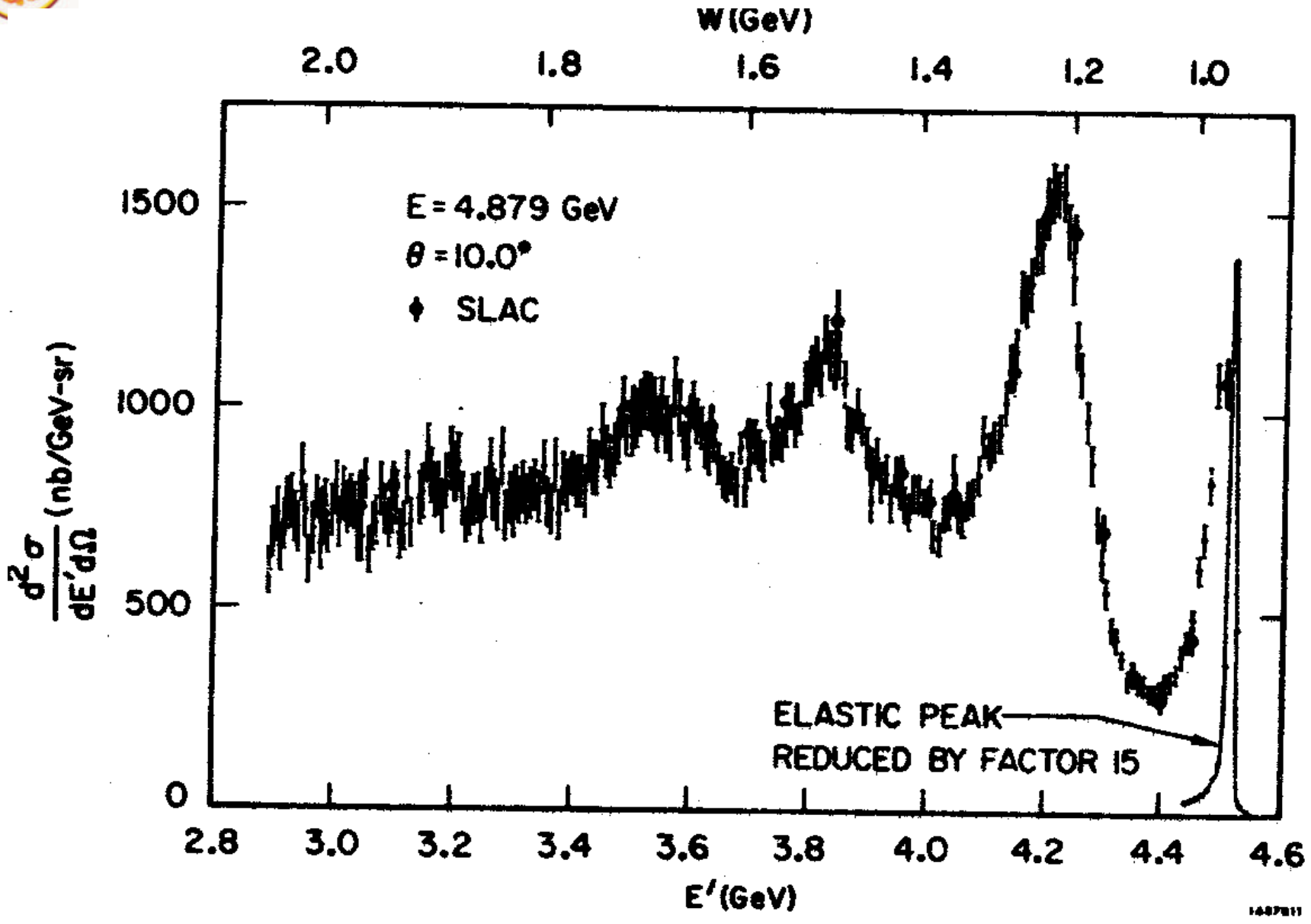
Accelerators circa 1930



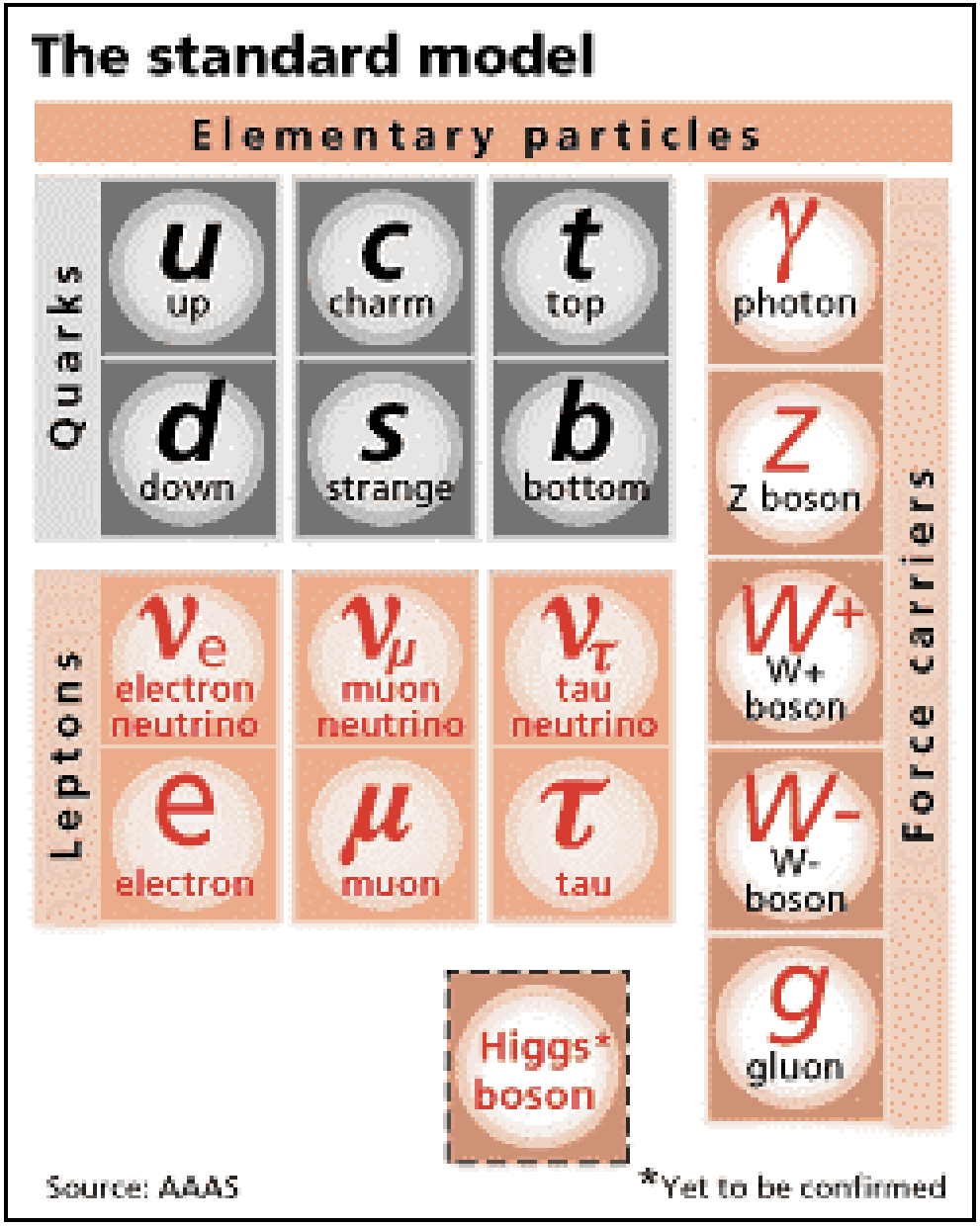
This Idea Did Not Work!



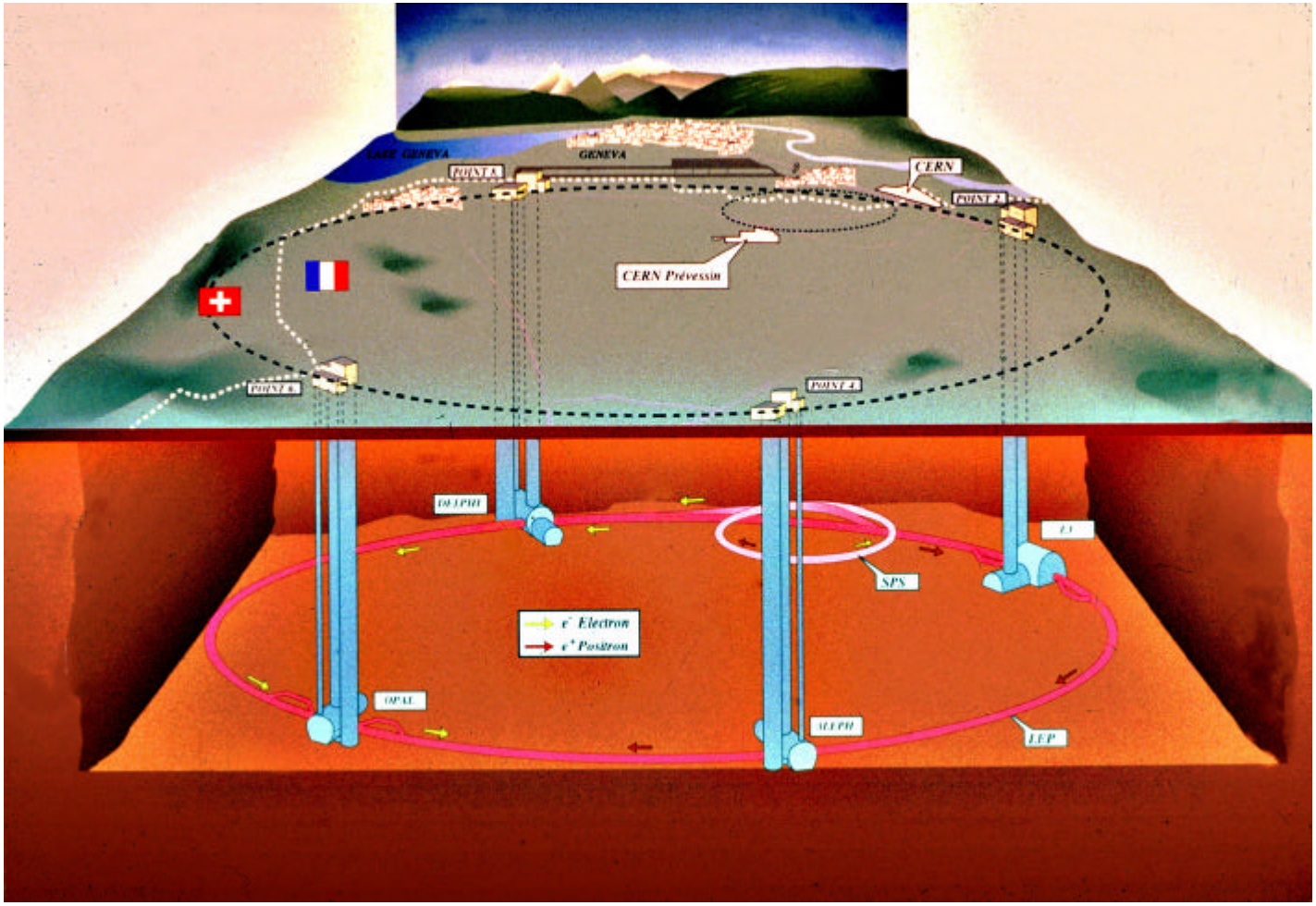
From Experiment to Theory



The Standard Model of Quarks, Leptons, Forces

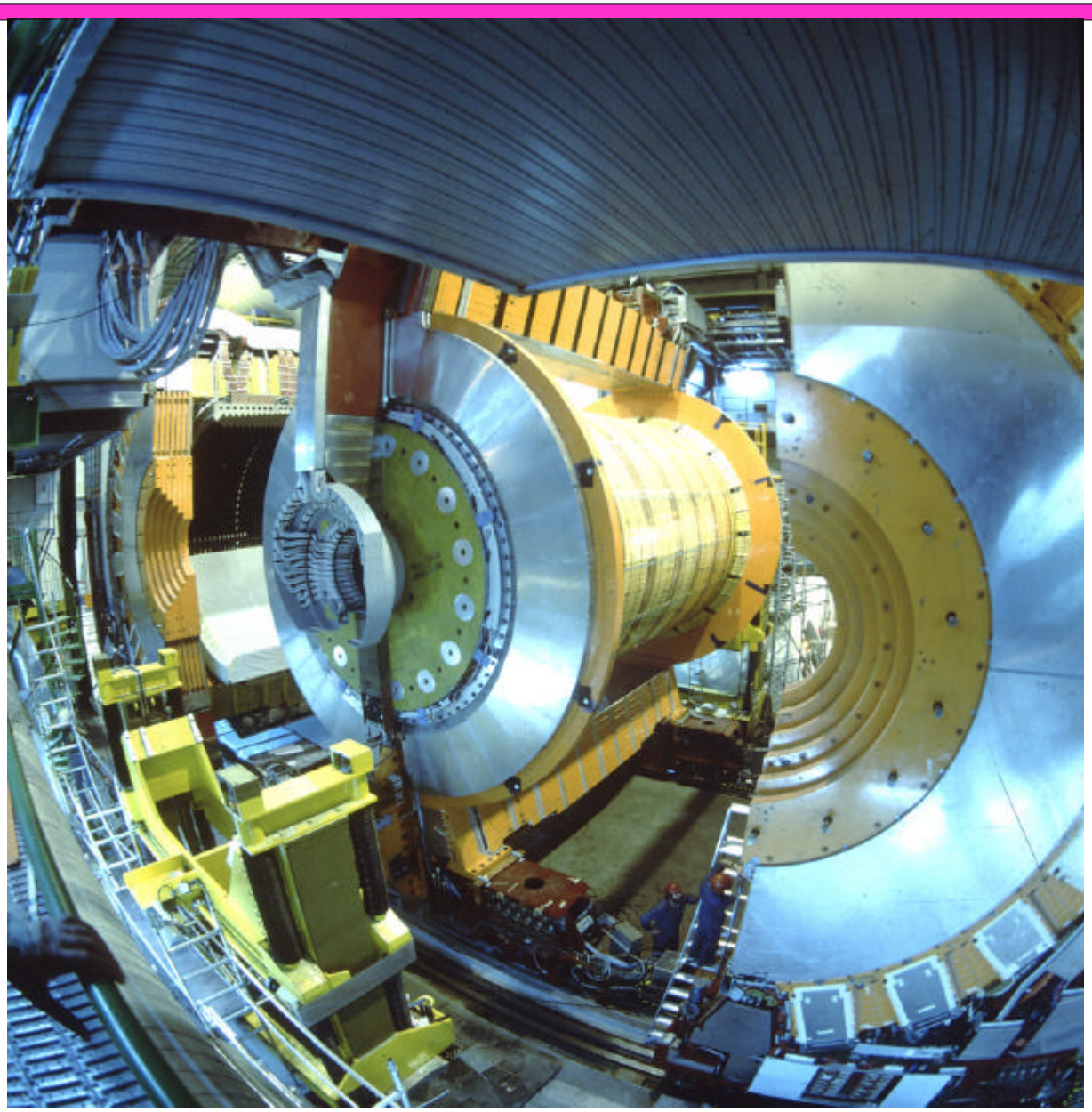


The 4 Underground Areas at LEP

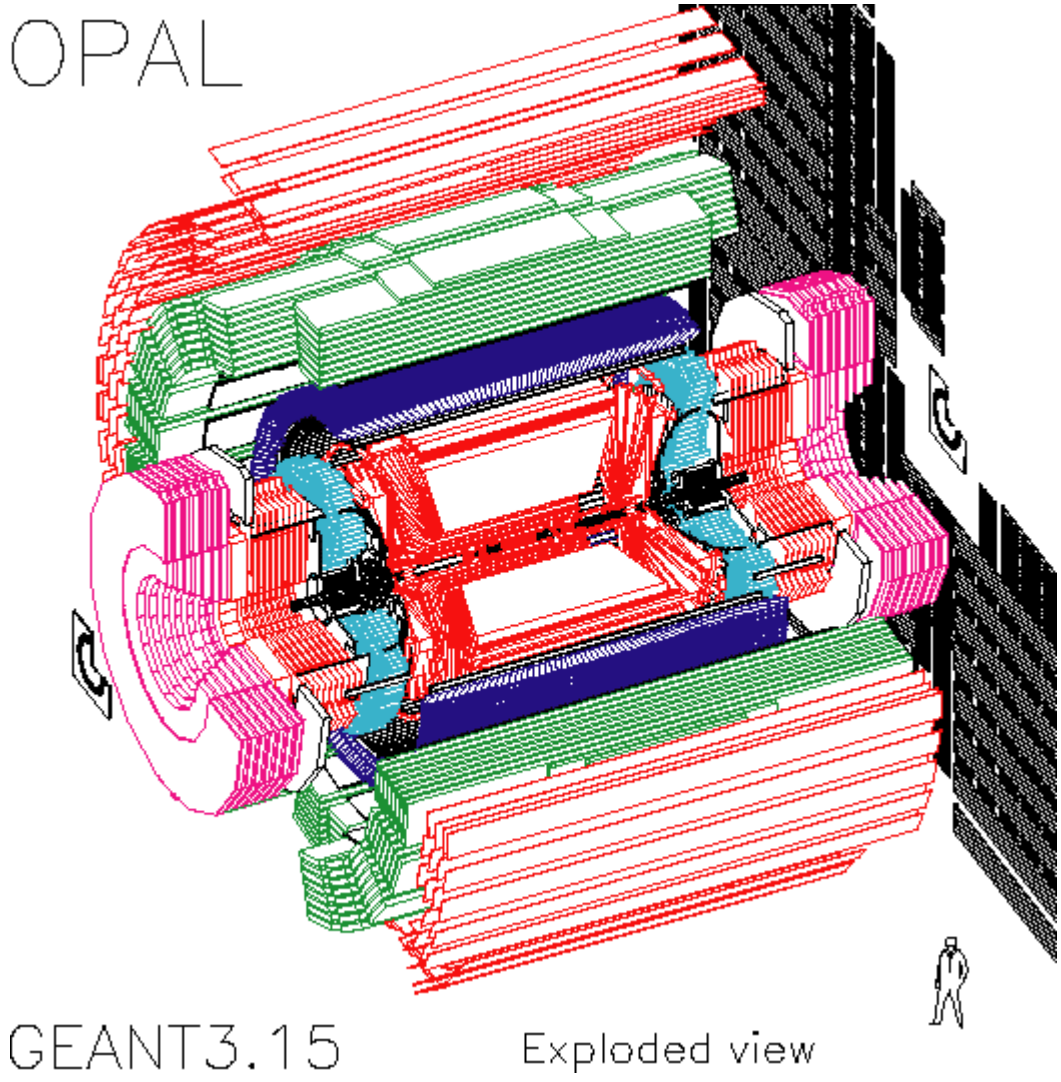


…and each experiment is a major facility

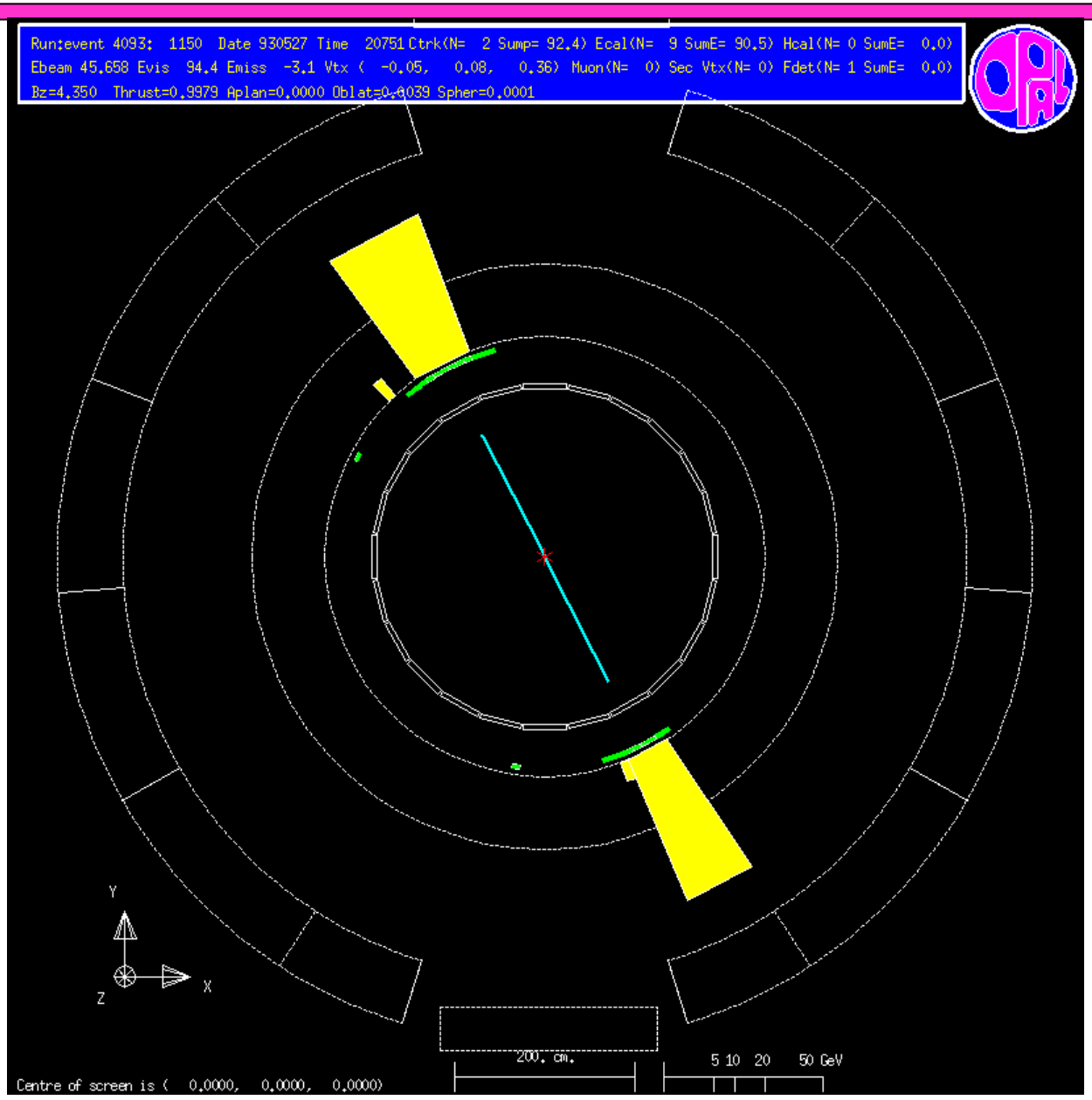
A Modern Experiment: OPAL



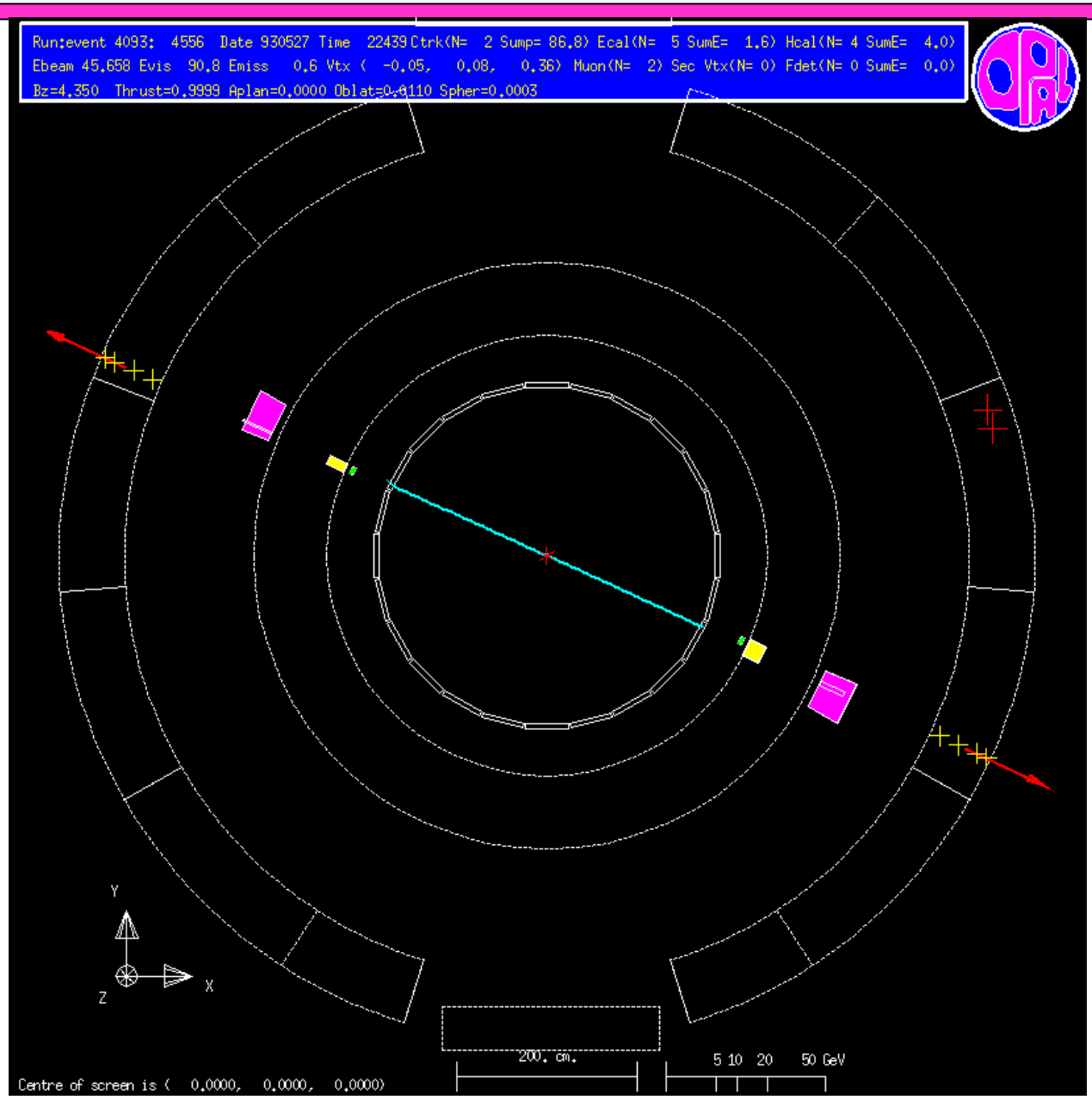
Detector in Schematic Form



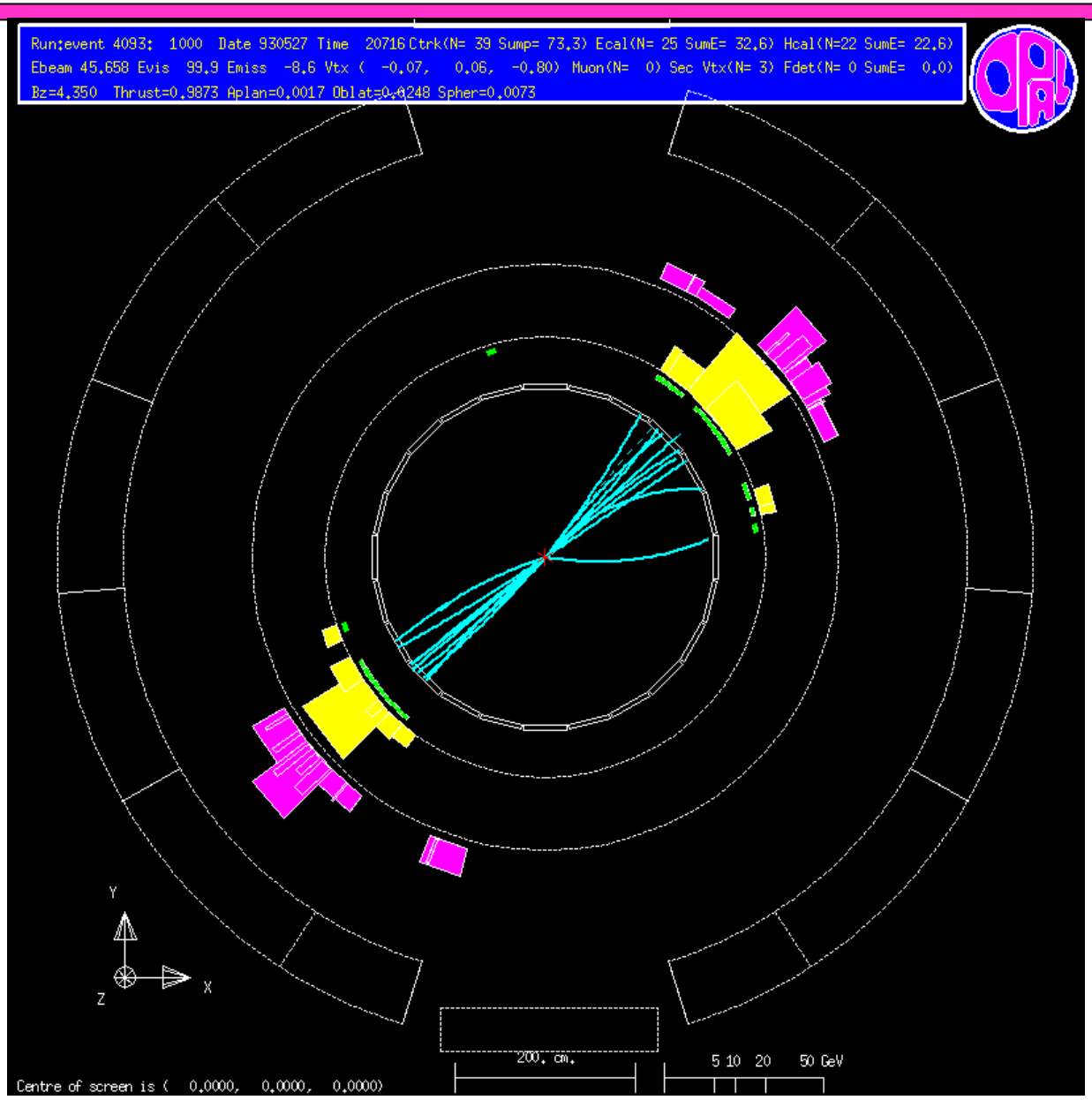
Event Picture from OPAL: Electron + Positron



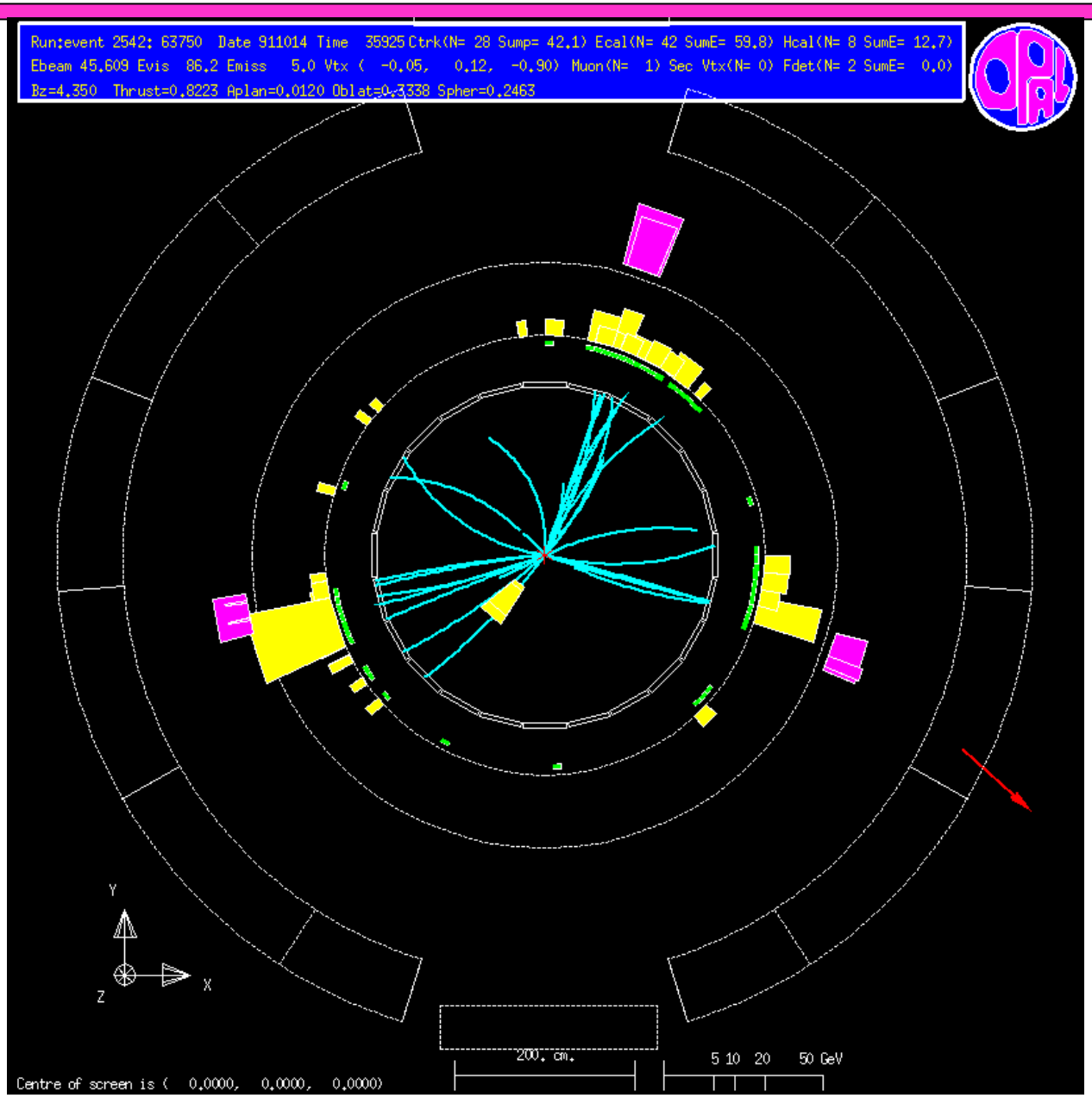
Muons


Run:event 4093: 4556 Date 930527 Time 22439 Ctrk(N= 2 Sump= 86.8) Ecal(N= 5 SumE= 1.6) Hcal(N= 4 SumE= 4.0)
Ebeam 45.658 Evis 90.8 Emiss 0.6 Vtx (-0.05, 0.08, 0.36) Muon(N= 2) Sec Vtx(N= 0) Fdet(N= 0 SumE= 0.0)
Bz=4.350 Thrust=0.9999 Aplan=0.0000 Oblat=0.0110 Spher=0.0003
Y
X
Z
200. cm.
5 10 20 50 GeV
Centre of screen is (0.0000, 0.0000, 0.0000)

Hadrons (quarks) -- Back-to-back jets



Jets Radiate a Gluon



A Good Place to Play Particle Physicist

- My colleague Terry Wyatt

- has designed a wonderful instructional site
  - http://hepwww.ph.man.ac.uk/~events/
  - (see it here)

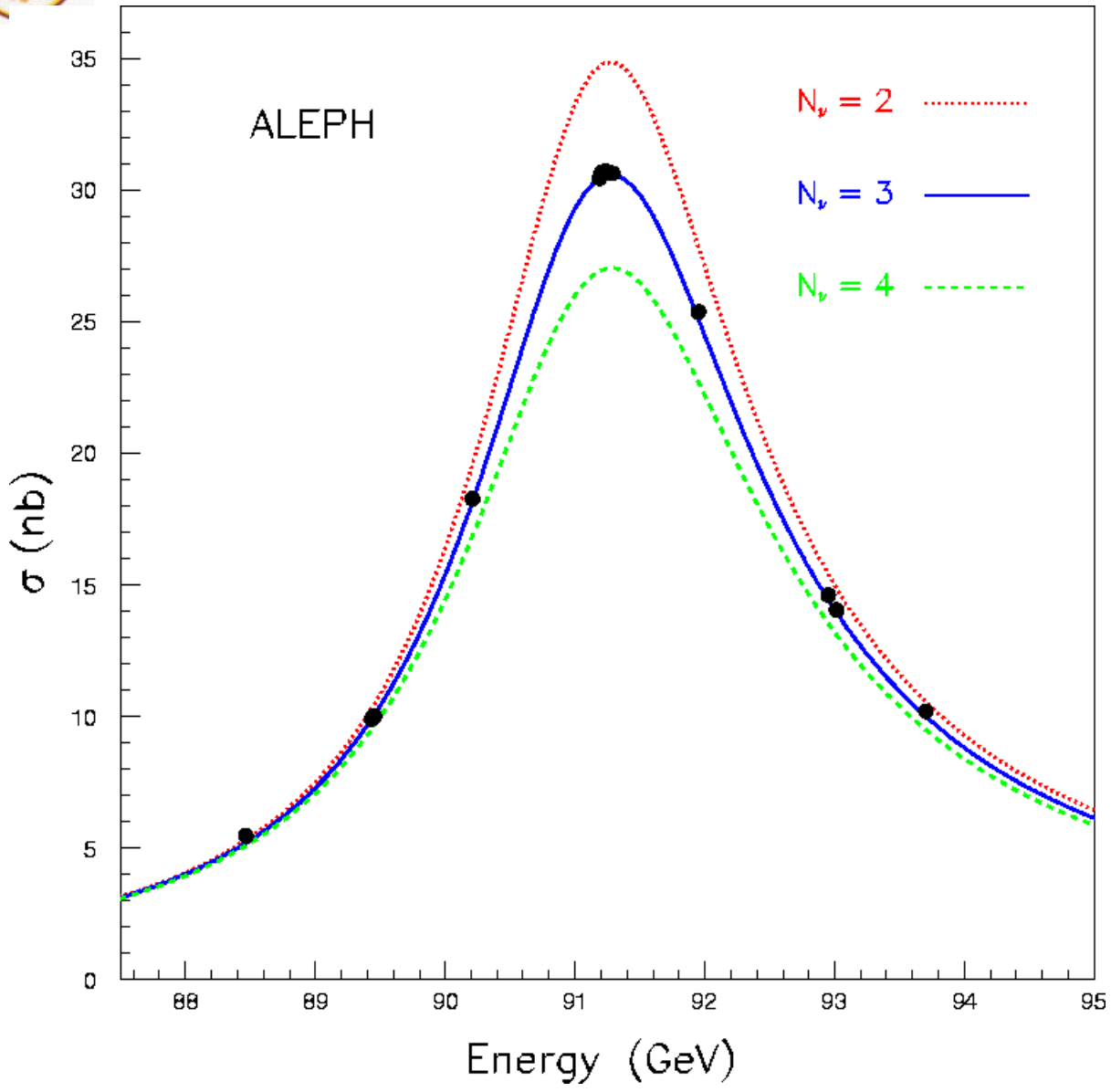
Z Physics

- LEP is an electron-positron collider:
  - we know the center of mass energy of the final collision
  - there are fewer particles than at a TeVatron experiment
-
- "Z Physics" means tests of the Standard Model:
  - Z mass is a fundamental parameter
  - Production rates are precisely modelled by the theory we are testing
  - These are precision measurements to test a theory (10^{-5})

- Example: $Z^0 \rightarrow q\bar{q}, l^+l^-, n\bar{n}, W^+W^-$

  - more families means more Z width

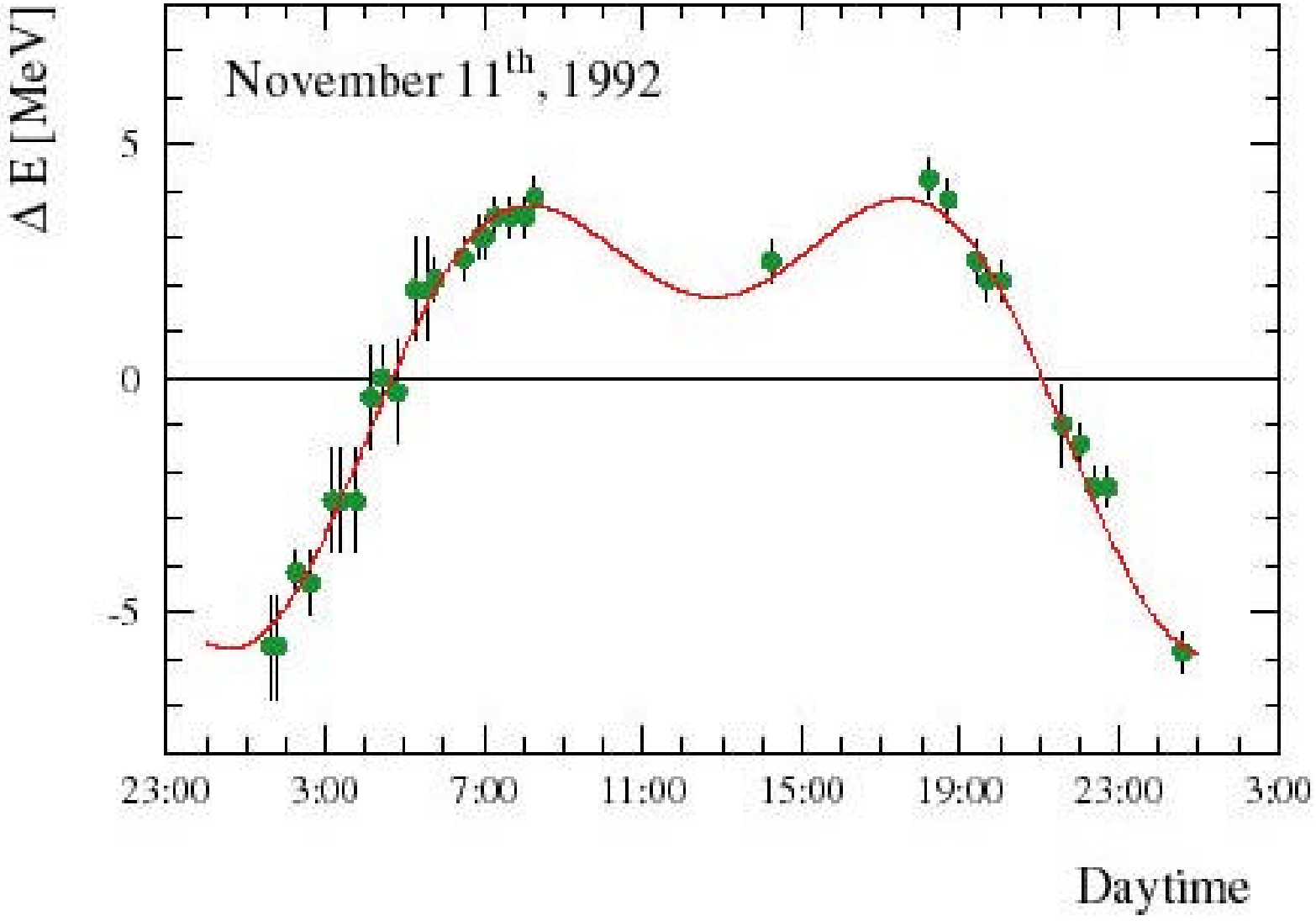
Z Physics 101: The Width of the Z Resonance



From this precision measurement, we get

$N_{fam} = 2.988 \pm 0.017$

Phase of the Moon and LEP Energy

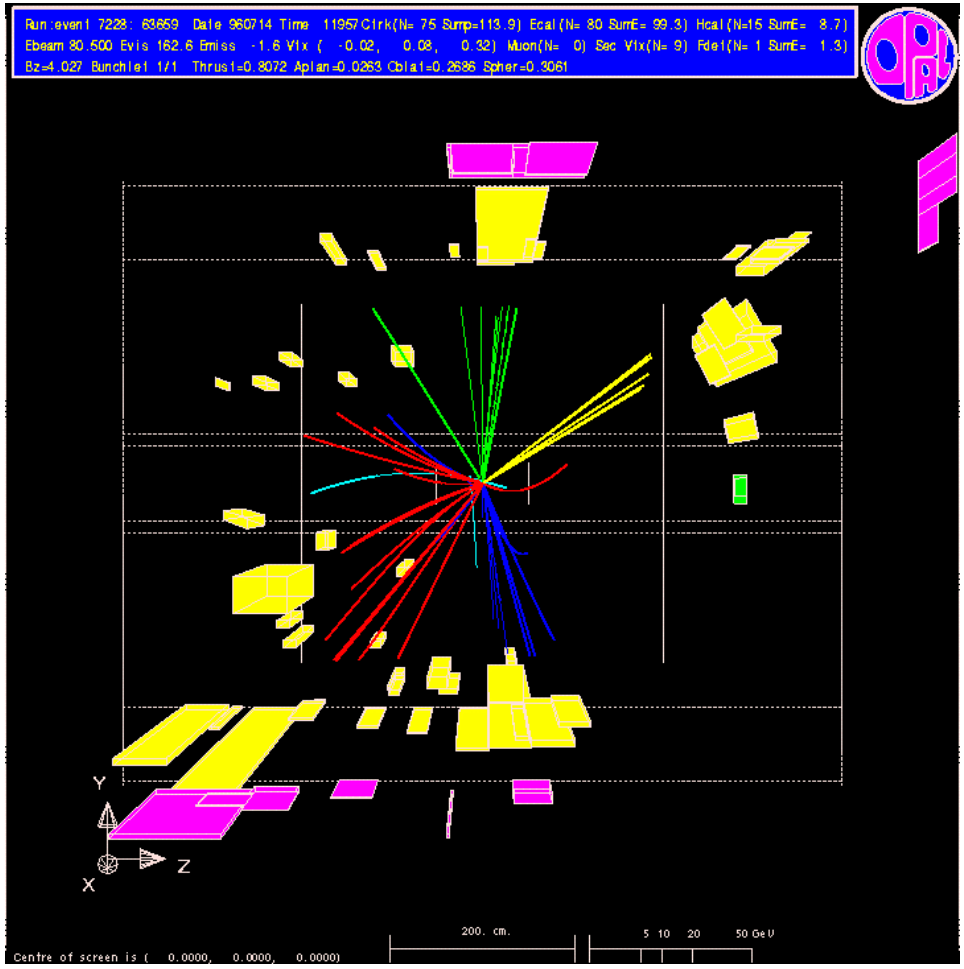


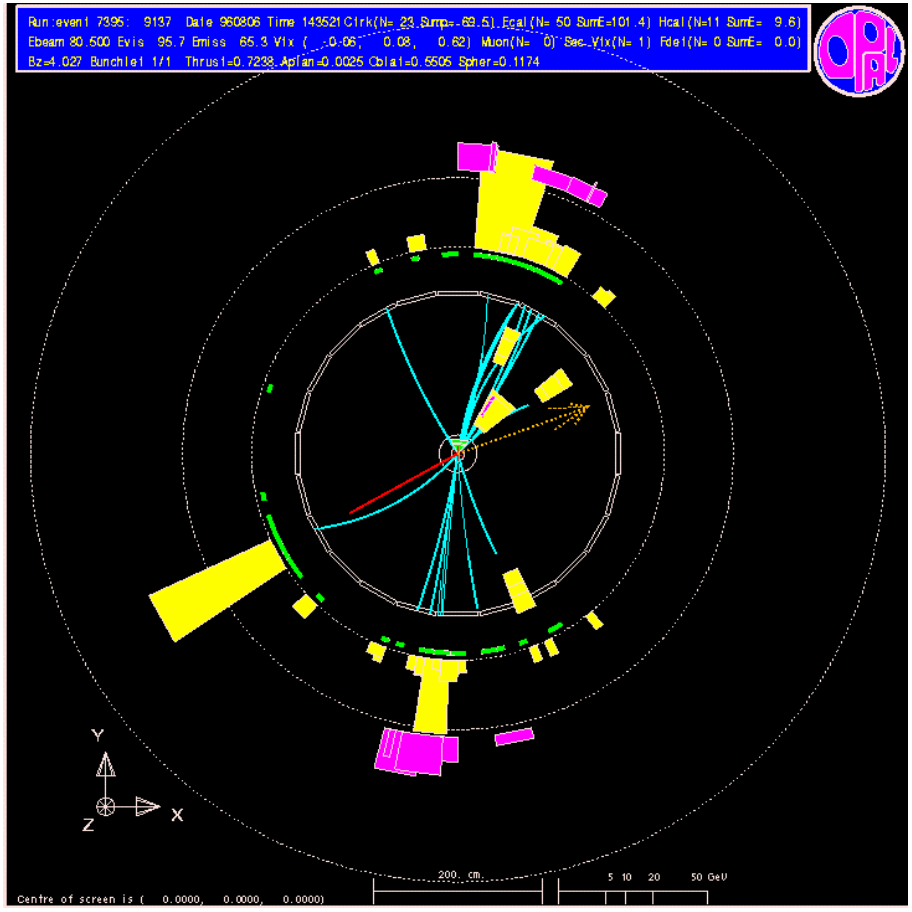
WW Production Tests Even Further

- Production of WW pairs as a function of energy needs a Z boson in the Standard Model
- The W mass is a fundamental parameter too

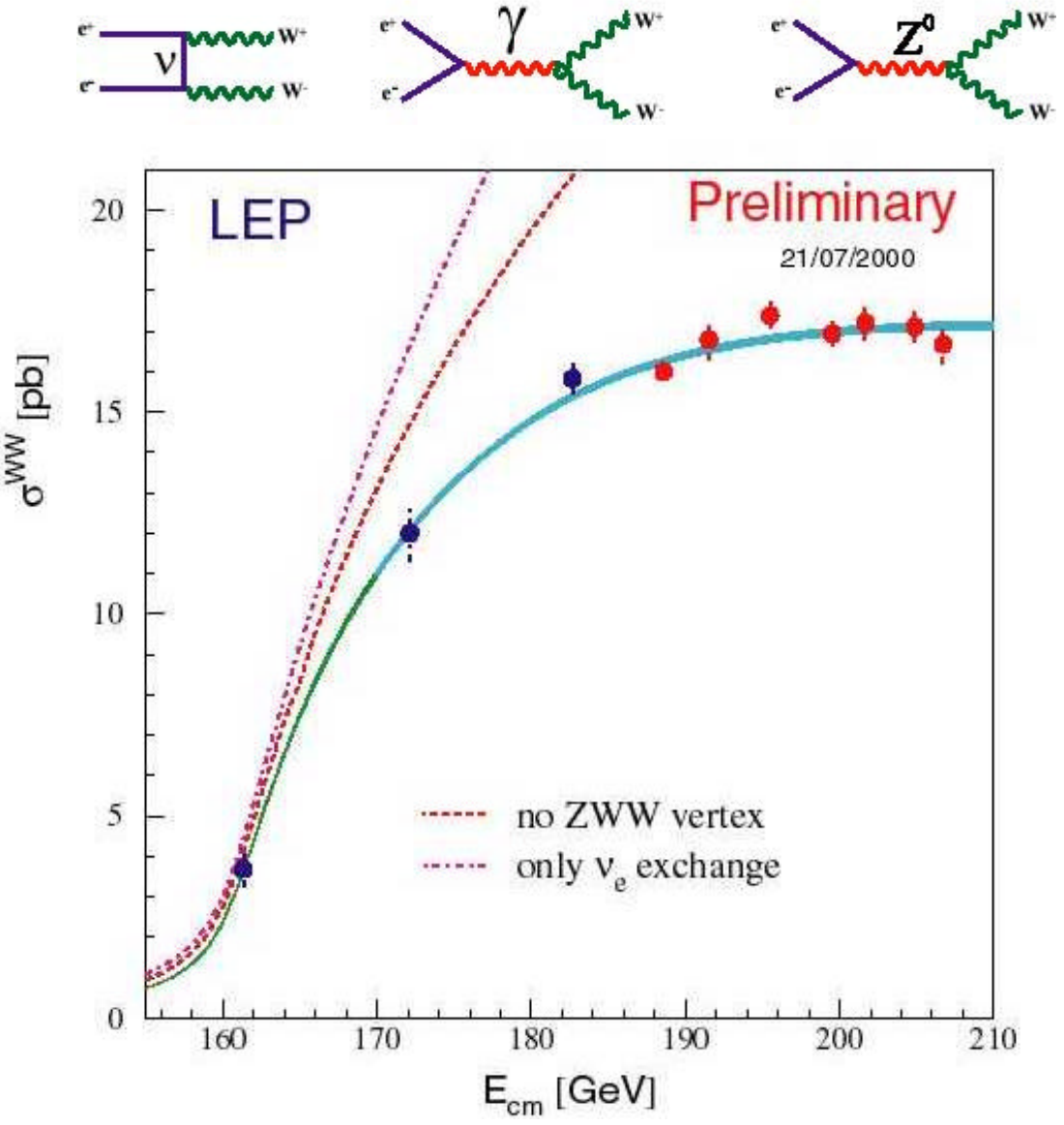
- Precision measurement of M_Z, M_W, Γ_Z can be a window to new physics

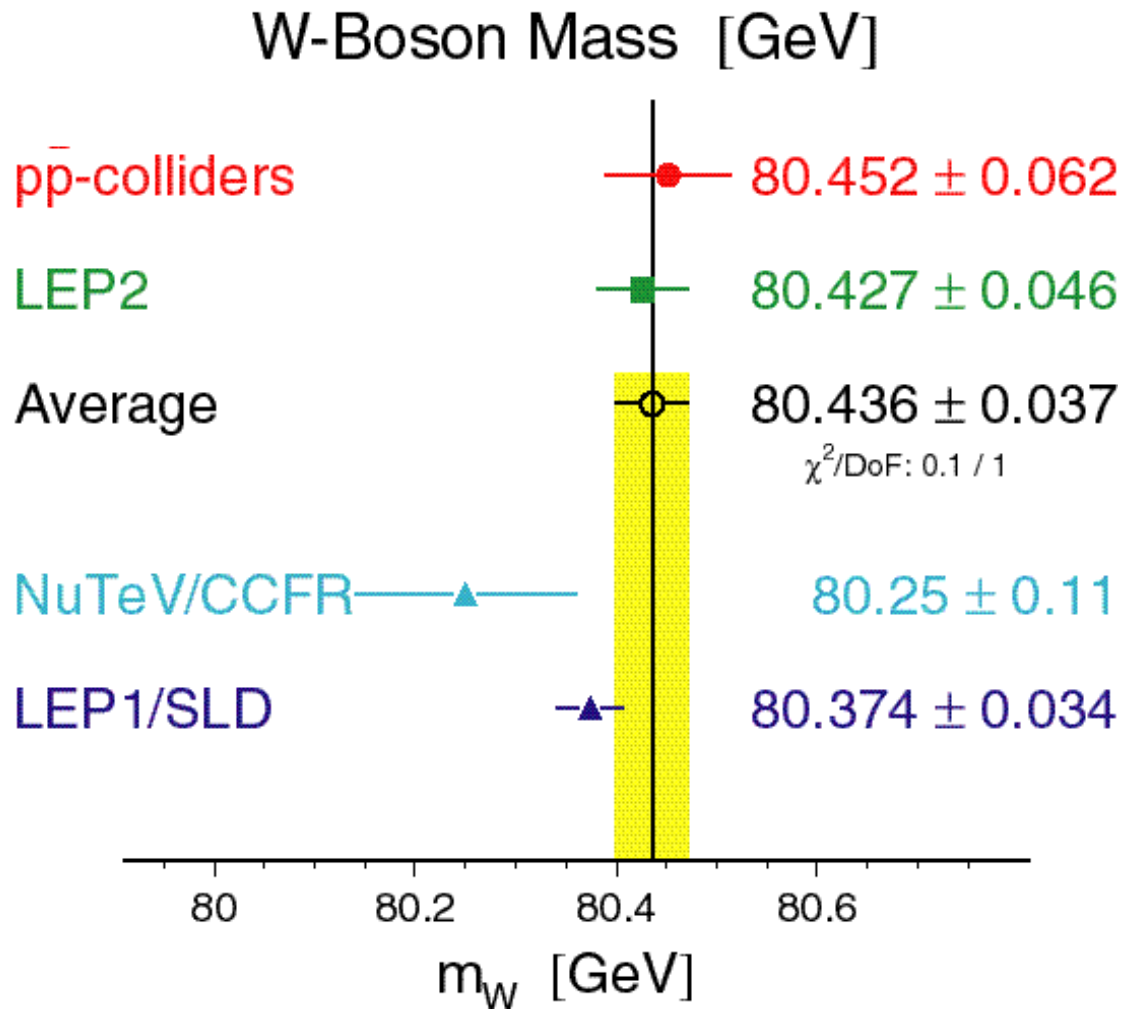
Clean WW Events



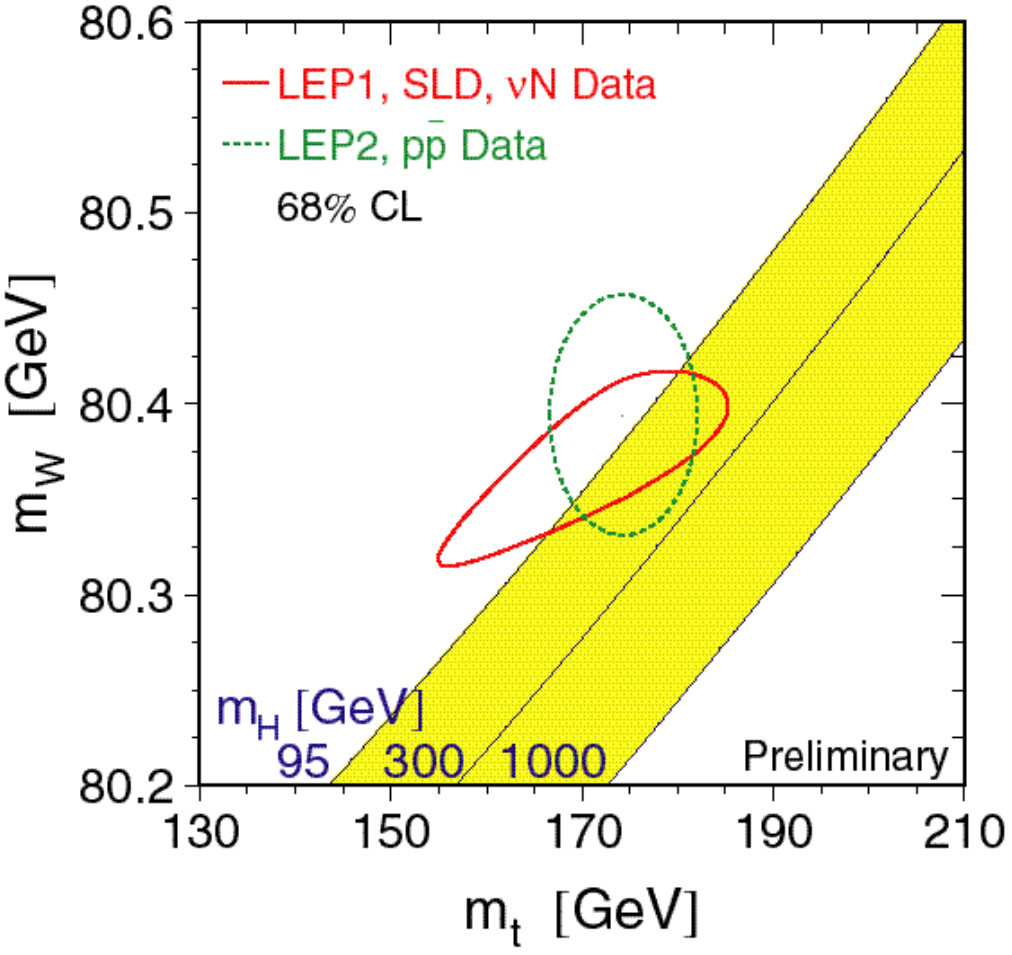


The Z Propagator Changes this Process Significantly

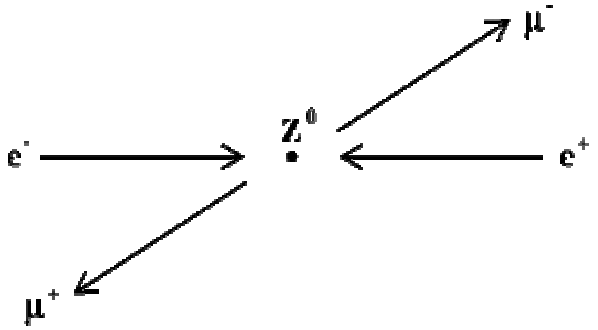


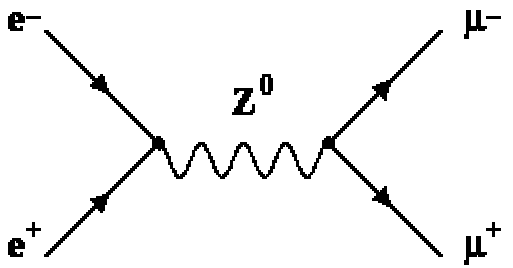

W-Boson Mass [GeV]
pp̄-colliders
80.452 ± 0.062
LEP2
80.427 ± 0.046
Average
80.436 ± 0.037
χ²/DoF: 0.1 / 1
NuTeV/CCFR
80.25 ± 0.11
LEP1/SLD
80.374 ± 0.034
80
80.2
80.4
80.6
m_W [GeV]

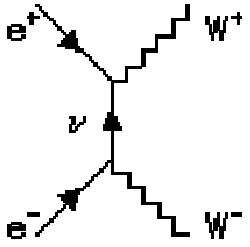
How These Measurements Suggest the Higgs Boson

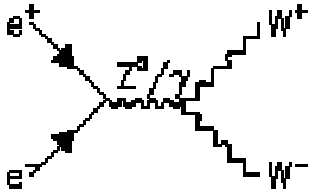


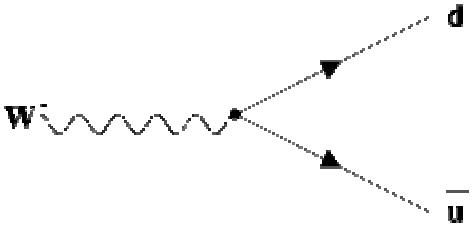
The Main Feynman Diagrams

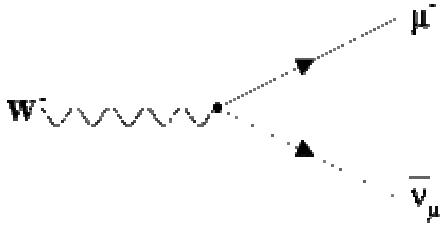


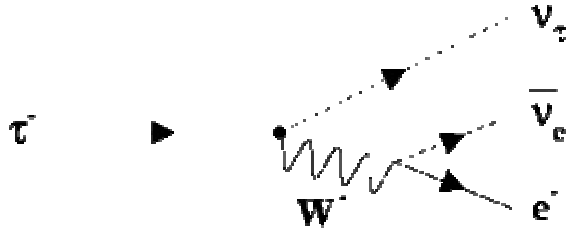


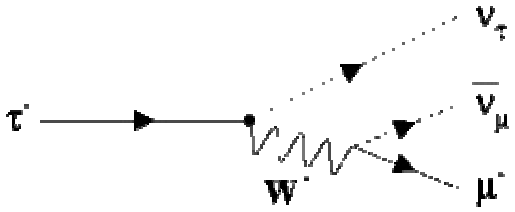




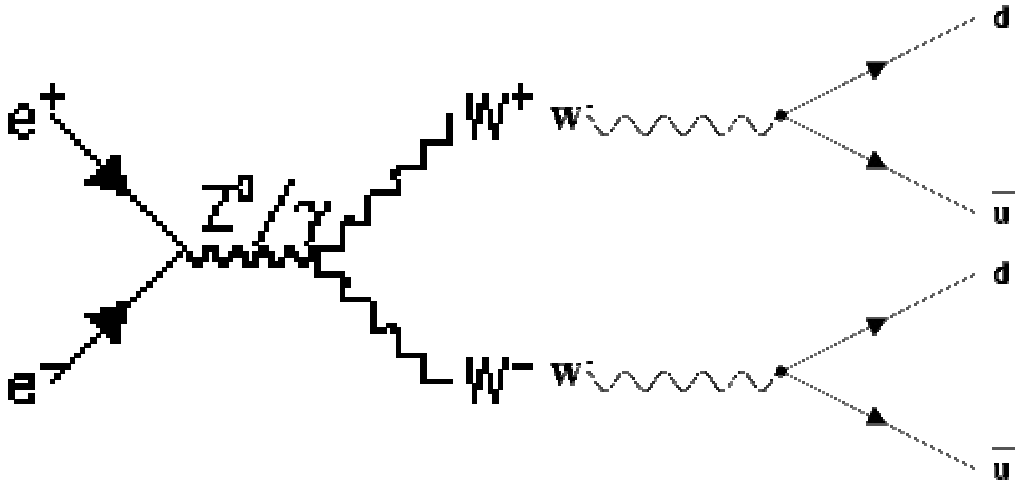


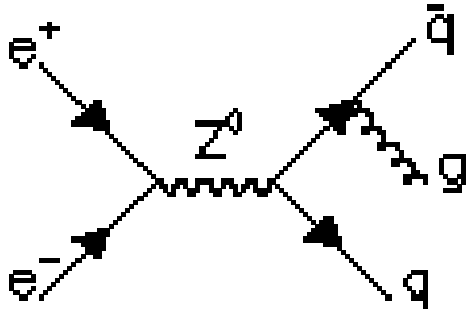






Signals and Backgrounds





Asymmetries