

# Outline

- Relativistic Kinematics
  - ▶ (4-momentum)<sup>2</sup> invariance, invariant mass
  - ▶ Hypothesis testing, production thresholds
  - ▶ Cross-sections, flux and luminosity
  - ▶ Particle lifetime, decay length, width
- Classification of particles
  - ▶ Fermions and bosons
  - ▶ Leptons, hadrons
  - ▶ Mesons, baryons
- Quark Model
  - ▶ Meson and baryon multiplets
  - ▶ Isospin, strangeness, c, b, t quarks
- Particle Interactions
  - ▶ Virtual particles and range of forces
  - ▶ Strong and weak decays, conservation rules
  - ▶ Parity, charge conjugation, CP
  - ▶ Weak decays of quarks
  - ▶ Colour charge, QCD, gluons
  - ▶ Charmonium and upsilon systems
- Electroweak Interactions
  - ▶ Charged and neutral currents
  - ▶ W, Z, LEP experiments
  - ▶ Higgs and the future
- LHC Experiments
- Future - introduction to accelerator physics

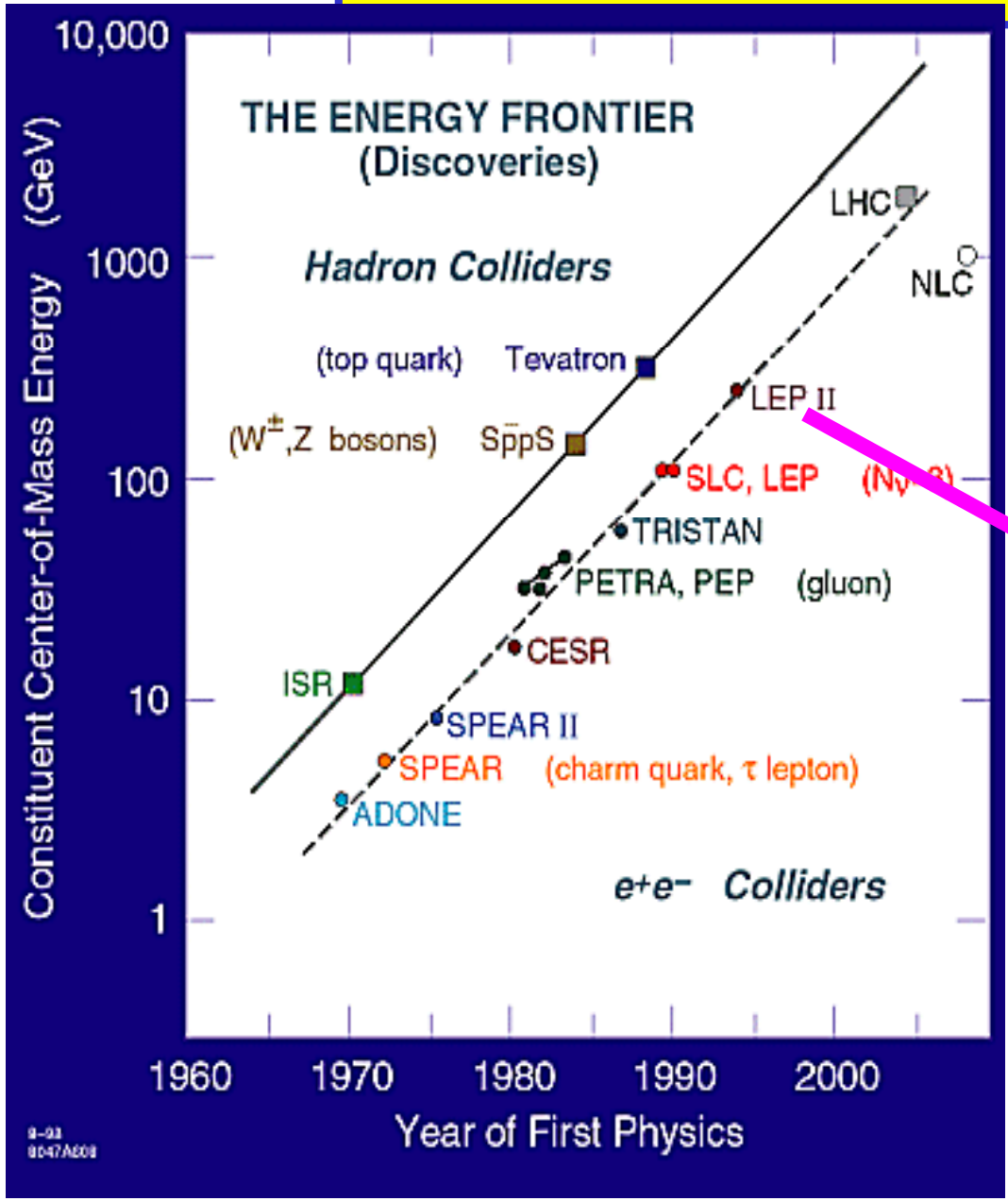
Today

- [Lecture 3 \(4 slides/page\)](#) - Particle decays and hypothesis testing
  - [Bubble Chamber web \(CERN/G.T.Jones\)](#)
  - [Kinematics. from PDG, J. Beringer et al. \(Particle Data Group\), Phys. Rev. D86, 010001 \(2012\)](#)

Previous  
lecture

- [Lecture 2 \(4 slides/page\)](#) - Relativistic kinematics and four momenta
  - Griffiths, pages 89-103
  - Williams, page 159
  - [Handout on kinematics and units](#)
  - Units: see also Perkins (3rd edition), pg.25.

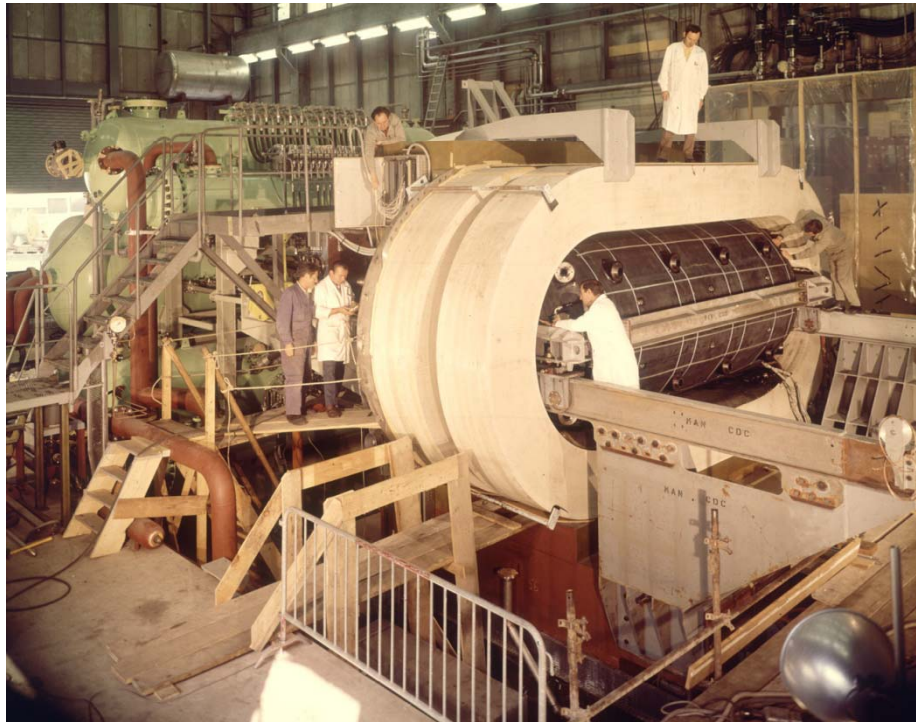
# "Energy Frontier" Accelerators



**LEP II at CERN**  
 $E_{cm} \sim 209 \text{ GeV}$   
 $P_{RF} \sim 30 \text{ MW}$

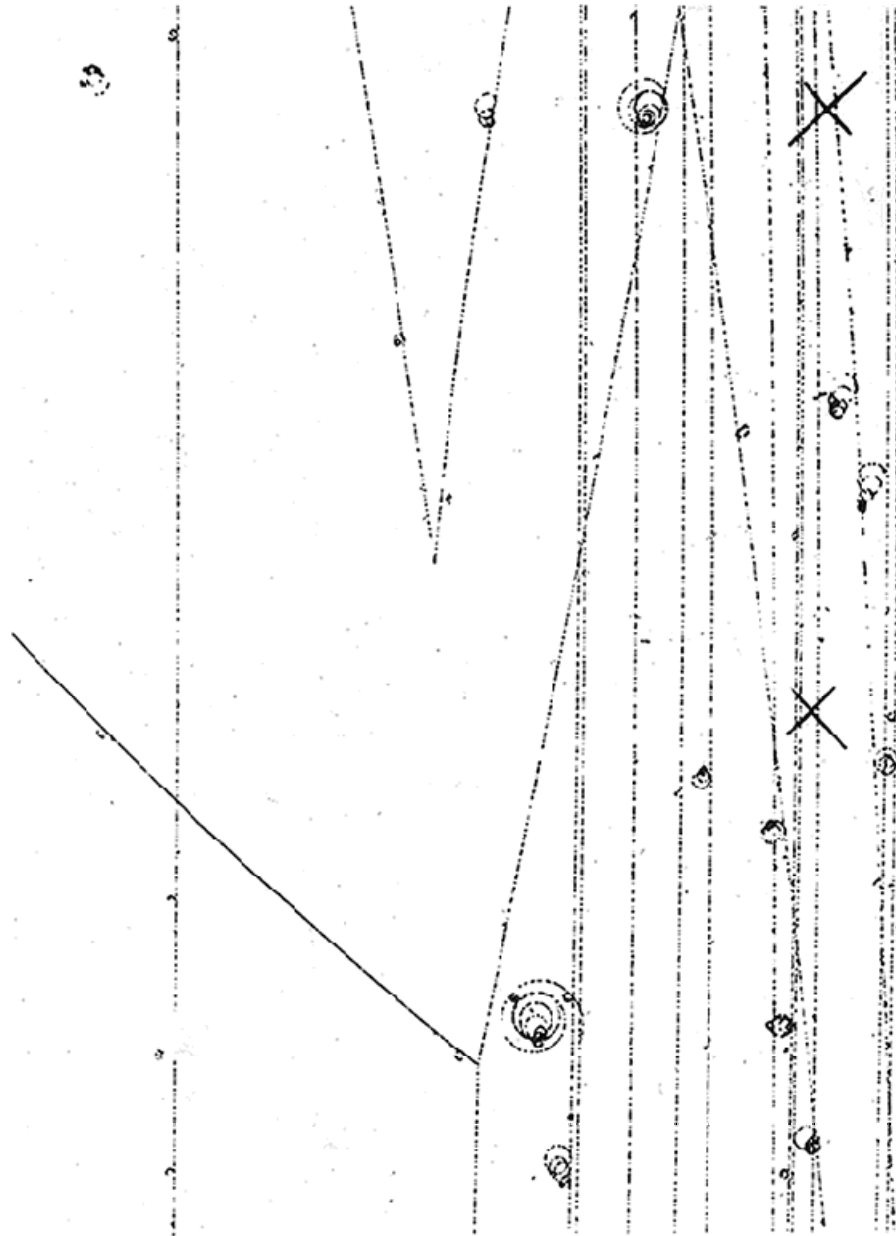
[c/o/ N.Walker]

# Bubble chambers



- Liquid (e.g.  $H_2$ ) at high pressure,  $\sim$ several atm.
- Pressure reduced as beam arrives (superheated)
- Ionisation along charged particles' trajectories causes boiling
- Bubbles form for  $\sim$ ms
- Flash photographs, multiple angles, 3d-reconstruction
- Increase pressure and repeat
- Slow to accumulate data
- Iconic, full angular coverage for detection

# Decays in bubble chamber



- Deduce momenta of charged particles by curvature in known and uniform magnetic field
- Reconstruction of neutrals from charged decay products
- Many detailed examples from course web page, incl. interactive demos.
- Worth a visit.