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Summary of Material Covered on Exam 2

1 Cross section calculation in scattering

Momentum transfer $q = p_i - p_f$ (4-momentum)

EM scattering from a potential, Rutherford scattering formula, dependence on charges
Exchanging heavy particles, range of interaction $r \approx 1 / m$, for exchange particle mass m
Weak interactions and W exchange
Interference of two diagrams in calculating scattering cross sections

2 Accelerators

Linear and circular accelerators
Radius of curvature in B field vs particle momentum in GeV: $p = 0.3Br$

Advantages and disadvantages of fixed target accelerators and colliding beams
Dependence of E_{cm} on beam energy for fixed target accelerators and colliders
Synchrotron radiation
- Dependence on γ and bend radius
- RF power needed for beams

Meaning and use of luminosity

3 Particle Measurements

Interactions of particles with matter
- Ionization loss (dE/dx) of charged particles
- Behavior of different particles in matter
- Showering behavior of electrons, photons and hadrons

Tracking chambers: Momentum measurement and sagitta
Measurement of K_S and Λ through their delayed decays to charged particles
Electromagnetic and hadron calorimeters
Charged particle ID techniques
- Time of flight
- dE/dx measurements
- Cerenkov radiation

Composition of large experimental detectors
- Tracking chambers
- Magnets
- Electromagnetic and hadron calorimeters
- Muon detectors

Finding unstable particles by taking invariant mass combinations
- Counting combinations, reducing combinatoric background

4 Statistics

Propagation of errors when adding/subtracting, multiplying/dividing, taking powers
Uniform, Gaussian, exponential, Poisson probability distribution functions
Definition of mean μ and standard deviation σ
    Estimating μ and σ from a sample
    Dependence of error on sample mean with N
General $1/\sqrt{N}$ behavior of errors
Concept of upper limits, determination of UL for Poisson and Gaussian errors
Combining multiple measurements in an optimal way (weighting by $1/\sigma_i^2$)
Statistical and systematic errors
    How to reduce statistical errors
    When taking additional data is useful or not useful

5 e^+e^- Physics

Understanding of $\sigma\left(e^+e^- \to \text{hadrons}\right)$ and $\sigma\left(e^+e^- \to \mu^+\mu^-\right)$
Meaning and measurement of R; value of R vs center of mass energy
Charmonium and bottomium resonances
QCD potential
Z physics, including measuring # of neutrino species

6 Weak Interactions

Weak interactions as exchange of W (charged current) or Z (neutral current) bosons
Order of magnitude calculations of decay rates & cross sections with simple Feynman diagrams
Universality in weak interactions with leptons.
    Evidence for universality
Weak interactions applied to quarks
    Charged currents and quark flavor changing
    Cabibbo angle and mixing, suppression of decay rates
    Extension of quark mixing to 3 generations, CKM matrix
Electroweak theory
    Unification of weak and EM interactions