Detectors for Particle Radiation

Prof. Dr. Otmar Biebel

Lecture:

Tuesday 14:15 - 16:45 Uhr Seminar Room H206

Begin: Lectures: 12. April 2016
Tutorial: 19. April 2016

Tutorial:

Tuesday 17:00 - 17:45 Uhr Seminar Room H206

Topics of the Lecture

- Introduction, Motivation
- Interaction between Particles and Matter
- Gaseous Detectors
- Liquid Detectors
- Semiconductor Detectors
- Scintillating Detectors
- Ionization Measurement
- electronic Signals & Processing
- Spacepoint Measurement
- Time Measurement
- Particle Identification
- Energy Measurement
- Momentum Measurement

on the web:

`http://www.physik.uni-muenchen.de/lehre/vorlesungen/sose_16/A_detektor/index.html`

Literature/Books

A small selection of books:

• Kleinknecht	Detektoren für Teilchenstrahlung	Teubner
• Grupen	Particle Detectors	Cambridge
• Knoll	Radiation Detection and Measurement	Wiley
• Leo	Tehniques for Nuclear and Particle Physics	Springer
• Blum, Rolandi	Particle Detection with Drift Chambers	Springer
• Ferbel	Experimental Techniques in High Energy Physics	World Scientific
• Sauli	Instrumentation in High Energy Physics	World Scientific
• Particle Data Group	`http://pdf.lbl.gov`	

and many more!

Details on Topics of the Lecture

1. Introduction, Motivation
   (a) Sources: Radioactivity, Accelerators, cosmic (solar, galactic, extragalactic) Sources of Particle Radiation
   (b) Tasks: Detection of Radiation, Dosimetry, Measurement of Spacepoint, Time, Energy, and Momentum, Particle Identification
   (c) Methods: Particle Physics, Electrodynamics, Optics, Atomic physics, Solide state and Semiconductor physics, Transport theory, analog and digital Electronics, anorganic and organic Chemistry
   (d) Applications: Medicin, Material Science, Geophysics, Particle physics, . . .

2. Interaction between Particles and Matter:
   (a) Elementary Particles, Interactions & typ. Interaction strengths
   (b) (heavy) charged particles: Energy loss by inelastic Scattering, Ionization, Bethe-Bloch-Formula, Čerenkov effect, Transition Radiation, Landau distriction, δ electrons
   (c) Electrons, Positrons: Bremsstrahlung, Radiation length
   (d) Photons: Photoeffect, Compton effect, Pair creation, Radiation Length
   (e) Neutrons: Nuclear capture, Nuclear reaction, elastic & inelastic Scattering, Moderation
   (f) Neutrinos: elastic Scattering, NC & CC reactions
   (g) Multiple scattering of charged particles: Coulomb scattering

3. Principles of gaseous Particle Detectors:
   (a) Ionization: Mechanisms, average Number of created Electron-Ion-Pairs
   (b) Transport of free Electrons & Ions: Drift and Mobility, Diffusion (field free), Recombination, Electron attachment
   (c) Electrondrift and electrondiffusion in fields: electr. fields, electr.+magn. fields,
   (d) Ionization amplification in gas
4. Principles of liquid Particle Detectors:
   (a) Ionization and Transport
5. Principles of Semiconductor Detectors:
   (a) Working principle of Semiconductors: Band structure, Doping, Charge carrier densities, Mobility, Recombination and Trapping
   (b) Semiconductor diodes: pn-Transition, Depletion depths, Capacitance
   (c) Ionization: Mechanisms, average Number of created Electron-Ion-Pairs
   (d) Operation: Bias-Voltage, Radiation damages
6. Principles of Scintillating Detectors:
   (a) Scintillation mechanisms
   (b) Organic, anorganic Scintillators: Light yield Wave length shifter
   (c) Photomultiplier, Avalanche-Photodiodes: Construction principles Fields of Operation, Limits

7. Ionization Measurement:
   (a) Gaseous Detectors: Ionization Chamber, Proportional Counter, Geiger Counter
   (b) Liquid Counters
   (c) Semiconduction Counters
   (d) Ageing of Detectors: Radiation Damages, chemical Reactions due to Radiation
8. electr. Signals and Signalprocessing: (Intermezzo)
   (a) typ. Signal Shapes
   (b) Pulse Forming
   (c) Pulse Discrimination and Time measurement: Time-Digital-Converter (TDC)
   (d) Pulse Shape Analysis and Charge measurement: Single-/Multi-Channel-Analyzer (SCA/MCA), Analog-Digital-Converter (ADC)
   (e) “Walk” and “Jitter” for Time measurement: Constant-Fraction-Triggering (CFT), Amplitudes&Rise time Compensated Triggering (ARC)
9. Spacepoint Measurement:
   (a) historic: Cloud Chamber, Bubble Chamber, Spark Chamber
   (b) Multiwire Proportional Chamber: planar, cylindric Geometry
   (c) Drift Chambers: Jet Chamber, Time Projection Chambers (TPC), Time Expansion Chambers (TEC)
   (d) Streamer Chambers
   (e) Nuclear Emulsino (DONUT, CHORUS)
   (f) Silicon Strip and Silicon Pixed detectors, and CCDs
   (g) Microstrip gas detectors (MSGC), Gas-Electron-Multipliers (GEM), Micromesh Gaseous Detectors (MicroMegas)
   (h) Scintillating Fibers
10. Time Measurement:
   (a) Scintillators
   (b) Resistive Plate Chambers (RPC)

11. Particle Identification:
    (a) Principles: characteristic Detection Reactions (e.g. neutrons)
    (b) Time-of-Flight Counters
    (c) Čerenkov Counters: Threshold counters, Ring imaging Counters (RICH), Transition Radiation Counters
    (d) multiple specific Energy Loss Measurement (Jet chamber, TPC)
12. Energy Measurement:
    (a) electromagnetic Calorimeter
    (b) hadronic Calorimeter and self compensating hadr. Calorimeter
13. Momentum Measurement:
    (a) Forms of Magnets for Particle Deflection
    (b) Tracking Detectors for Collider Experiments