08 - Miscellaneous and historical detectors

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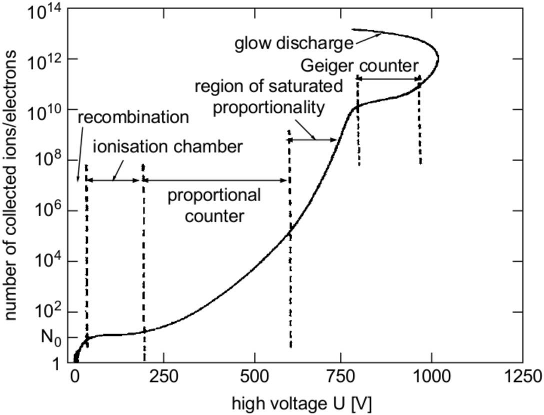
Version 2

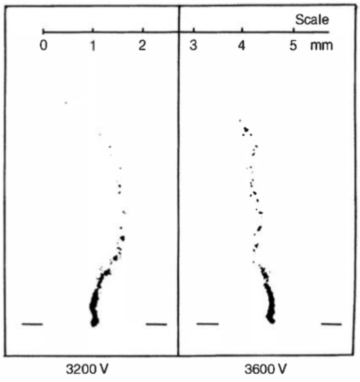
Streamer mode of gas-filled detector

- Different mode of operation of Geiger or proportional detector
- Propagation of avalanches controlled by absorption of UV photons
- SQS - self-quenched streamer



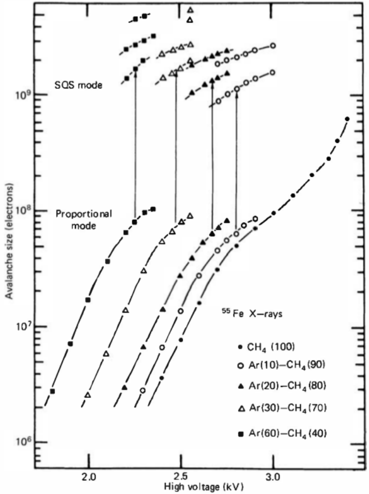
Streamer mode of gas-filled detector

- Avalanche propagates radially outwards from the anode, depends on voltage
- Formed positive space charge of ions of conic shape, field highest at the tip
- New avalanches created on the tip of cone of positive charge



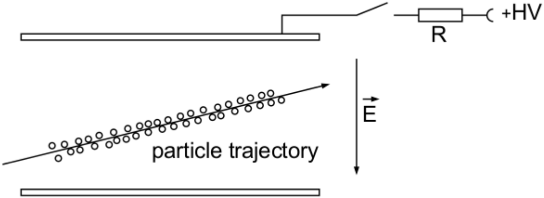
Transition from proportional to SQS mode

- Streamer pulses larger by order of magnitude compared to proportional mode
- Both modes may be observed in some range of voltage
- Streamer formation created by anode wire of radius larger than in Geiger detector



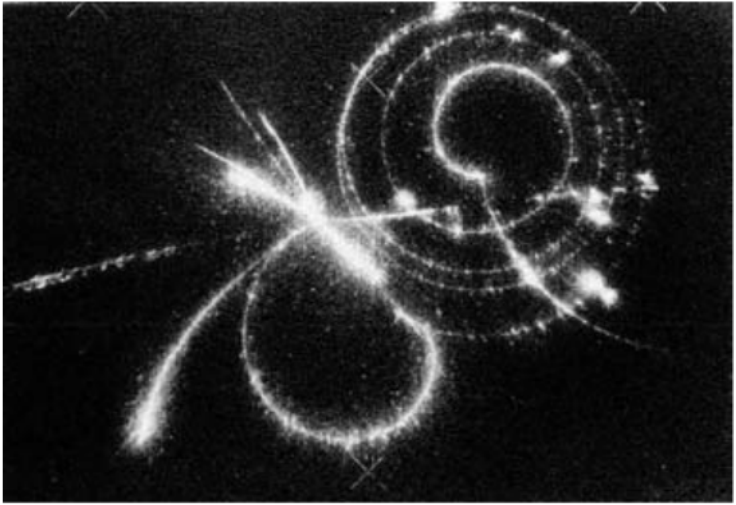
Streamer chambers

- Short pulse of high voltage applied to electrodes after passage of charged particles
- Streamers generated along the track during the pulse
- As the pulse is short, streamers develop around the particle trajectory
- Trajectory photographed through one electrode of transparent wire mesh, each streamer seen as one luminous point in this projection



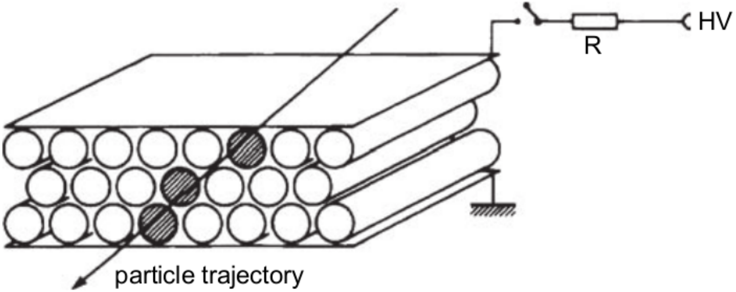
Interaction of antiproton with neon nucleus in streamer chamber

- Produced π^+ which spirals anticlockwise
- Decay into muon, also spirals in magnetic field
- Muon decays into positron which escape the chamber



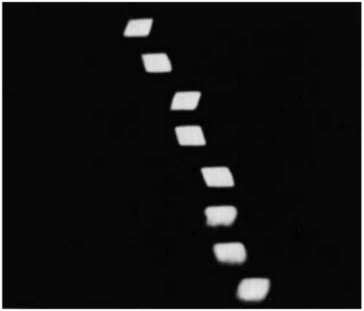
Neon-flash-tube chamber

- Pulse of high voltage on electrodes after passage of charged particle
- Glow discharge in over whole length of the tube
- Tubes photographed or signal readout by pick-up electrodes at the end of the tubes



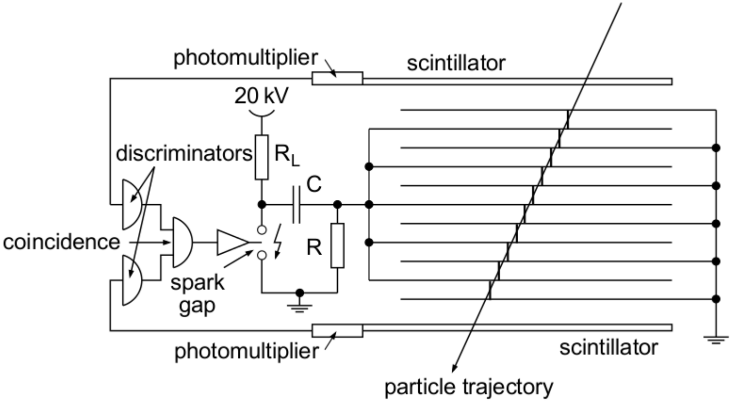
Parallel cosmic muons in neon-flash-tube chamber

- Single muon in polypropylene plastic tubes

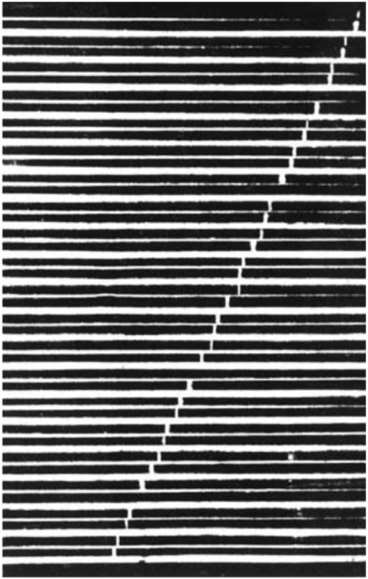


Spark chambers

- High voltage pulse triggered by coincidence in scintillators below and above the chamber
- Pulse amplitude set for gas amplification large enough for spark discharge
- Sparks between plates follows the original particle trajectory, providing 3-dimensional tracking
- Clearing field to remove positive ions from detector volume



Cosmic-ray muon in multi-plate spark chamber

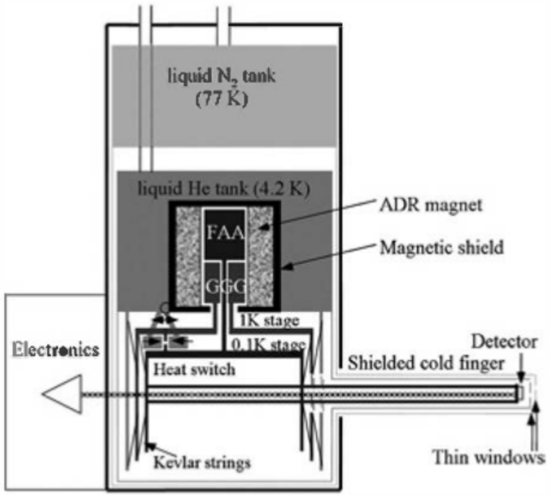


Liquid ionization and proportional counters

- Liquid phase of noble gases, Xe or Ar
- Operation as ionization or proportional chamber
- Needed high purity of liquid for efficient charge collection
- Cryogenic temperature
- Charge collection and/or scintillation light

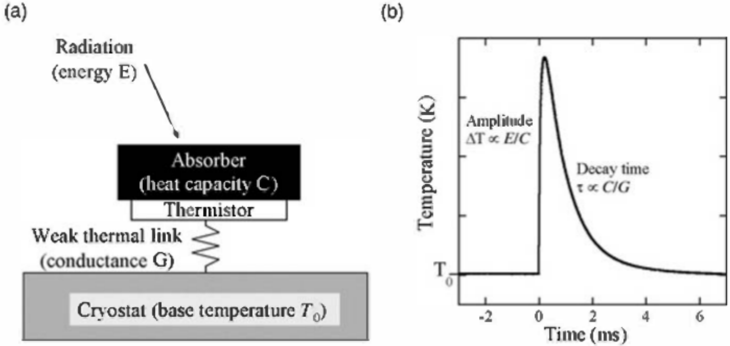
Cryogenic detectors

- Better energy resolution than silicon or HPGe, operated temperature ∼0.1 K
- Temperature below liquid He (4.2 K) achieved by adiabatic demagnetizatinon refrigerator (ADR)
- Spins in paramagnet aligned by strong magnetic field, then field slowly removed (adiabatic) while spins absorb phonons, leading to cooling effect



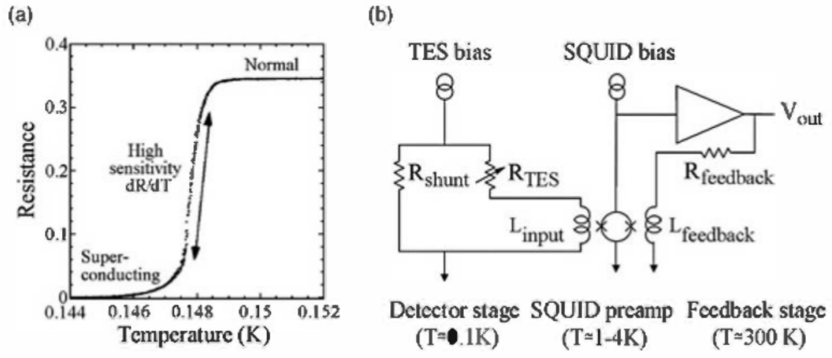
Semiconductor microcalorimeter

- Measured increase in temperature by absorption of ionizing radiation
- Orders of 10^{-10} K
- Absorber coupled to thermometer, weak coupling to cryostat
- Precise energy resolution, X-ray astronomy (NASA)



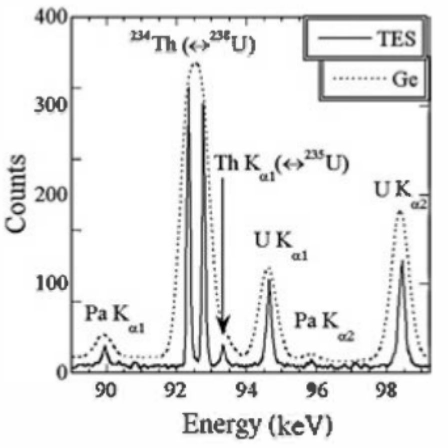
Superconducting transition edge sensor (TES)

- Detector operated at transition between normal and superconducting state
- At constant voltage, heat of absorbed radiation increases resistance and current decreases
- Power imposed on detector by voltage and current decreases, detector returns to nominal operating point
- Current pulse transported to preamplifier by induction coupling



Gamma spectrum of low-enriched uranium by TES

- Dashed line - spectrum recorded by germanium detector



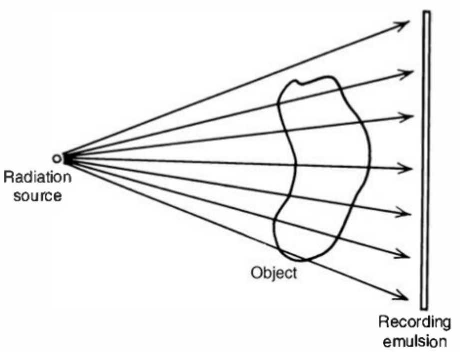
Magnetic microcalorimeters

- Magnetization of sensor changed by absorption of energy
- In magnetic material in external field, energy levels spaced according spin (Zeeman effect)
- At very low temperature, only lower level occupied
- After absorption of energy, electron excited to state with opposite spin, magnetization of sensor changes
- No need for external bias and power bias removal
- Change of magnetization detected in similar way as in TES
- Energy resolution about three orders of magnitude better than in TES

Photographic emulsion

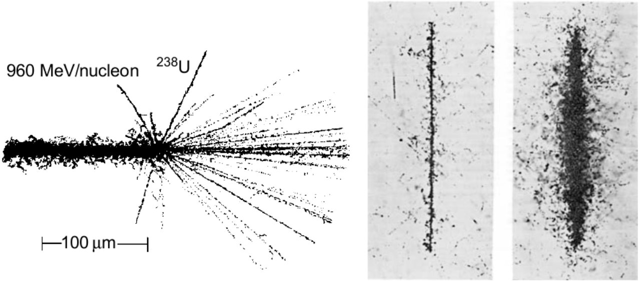
- X-ray discovery using photographic film
- Emulsion of silver halide grains in gelatin matrix, supported by glass or film material
- Ionizing radiation interacts as visible light, neutral atoms of silver created in some grains
- Development of emulsion - all grains with neutral atoms converted to metallic silver, such grain is then visible
- Fixing of emulsion - undeveloped grains dissolved away

Radiographic film



- Object casts shadow to incident radiation from point source
- Exposure set for suitable number of developed grains
- Sensitivity increased with use of sandwich structure of films and foils of converter materials
- Large areas of X-ray films for cosmic ray detection

Nuclear emulsion

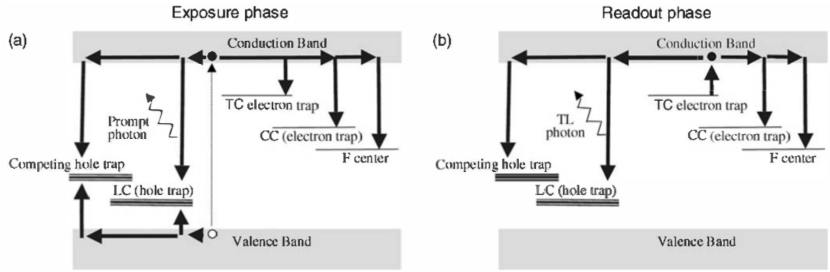


- Recording of individual tracks, density measures dE/dx
- Finer grains compared to commercial or X-ray films
- Higher sensitivity, MIP should produce enough developed grains to be recorded
- 3D track reconstruction with use of focal plane of optical microscope
- Used at OPERA experiment of tracking of τ decays, planned as annihilation detector for AEgIS experiment

Silver-halide crystals

- Larger sensitive volume compared to emulsions
- Ag^+ ions and free electrons in conduction band formed along charged particle trajectory in AgCl crystal
- Metallic silver produced by reduction of ions
- Development illumination, new electrons reduce further Ag^+ ions, they reduce to already existing metallic Ag
- Microscopically-visible clusters of Ag formed at points of Ag^+ ions from primary interaction

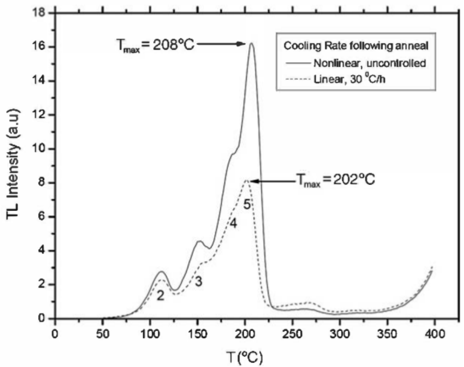
Thermoluminiscence detectors



- Incident radiation in inorganic crystal creates electron and hole pairs as in scintillator
- Charges trapped at levels within bandgap for indefinite amount of time
- Material with deep traps at energies far from bandgap edges
- Continues irradiation creates population of trapped charges, number proportional to integrated deposited energy
- Readout by thermally or optically stimulated luminiscence
- Dosimetry or cosmic ray detection

Readout of thermoluminiscence detector

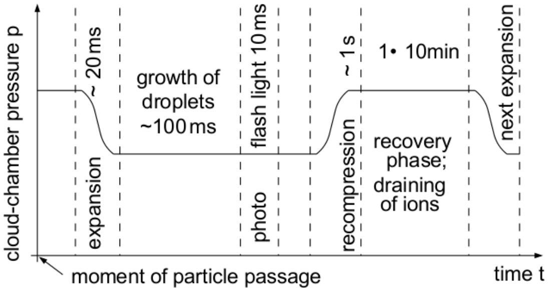
- Glow curve gives intensity of thermoluminiscence as a function of temperature



- Light production efficiency is the ratio of energy released in thermoluminiscence photons to absorbed energy of incident radiation
- Optically stimulated luminiscence - energy to release trapped charges delivered by laser light
- Allows remote reading by optical fibers of position-sensitive detection
- Application for cosmic ray detection via electromagnetic showers, sandwich structure of position-sensitive thermoluminiscent layers and lead absorbers

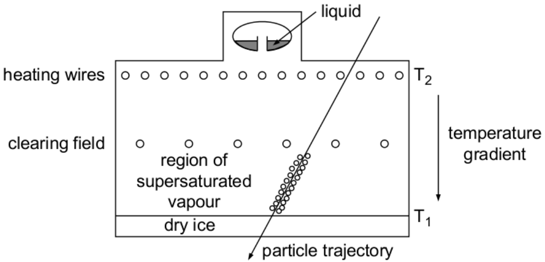
Cloud (Wilson) chamber

- Positron discovery 1932



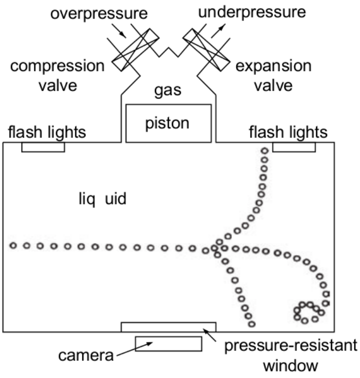
- Expansion cloud chamber: mixture of gas-vapor at saturation pressure
- Positive ions by crossing charged particle
- Adiabatic expansion after passage of particle, condensation at the ions
- Droplets created along particle trajectory
- Recompression of mixture into initial state

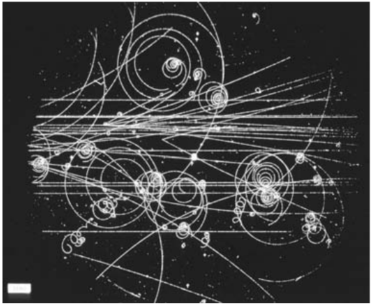
Diffusion cloud chamber



- Permanently sensitive, can not be triggered
- Region of permanently super-saturated vapor created by constant temperature gradient
- Droplets along particle trajectory in sensitive volume defined by region of super-saturated vapor
- Clearing field to remove positive ions

Bubble chamber





- Volume of liquid at pressure, close to boiling point
- Expansion by piston before expected event, synchronized with accelerator operation
- Boiling temperature of liquid exceeded by pressure reduction
- Bubbles formed at positive ions left by passage of charged particle
- Bubbles illuminated and photographed for visual analysis
- High spatial resolution, good for rare complex events (decay topology, neutrino interactions)