Chap. 19 – Miscellaneous Detectors

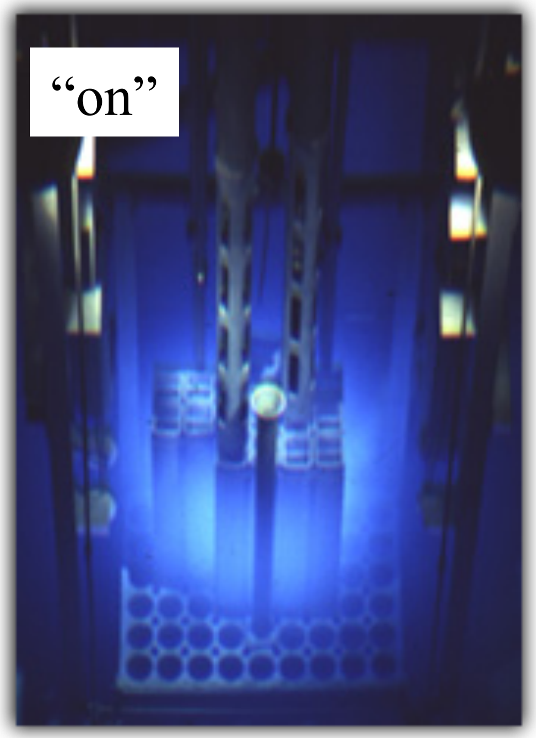
Up to this point:
Gas-filled detectors … ion chambers, proportional counters, GM counters
Scintillators … organic, inorganic
Semiconductor-based detectors … Si or Ge

Other possibilities:

Cerenkov Radiation
Liquid-filled detectors … bubble chamber & rare gas
Thermal calorimeters … bolometer
Other solid-state materials: films, TLDs, track-detectors

Miscellaneous Detectors: Cerenkov Light

Cerenkov light is emitted when a particle moves through a dielectric medium at a velocity that is faster than the phase velocity of light in that medium. (e.g. in water n=1.33, $c=0.75c_{vac}$) The effect is one of a shockwave caused by the electromagnetic interaction of the particle with the atoms. At low velocities any (low energy) photons emitted during the displacement/replacement of the atoms destructively interfere …the number of photons is proportional to the velocity and to the frequency of the emitted light (n is a function of ν which cuts off the spectrum).



U.Missouri, Rolla
(200kW reactor)

$$n = \sqrt{\varepsilon_{rel}\mu_{rel}}$$

$$\mu_{rel} \sim 1 \quad \textit{nonmagnetic materials}$$

Miscellaneous Detectors: RICh

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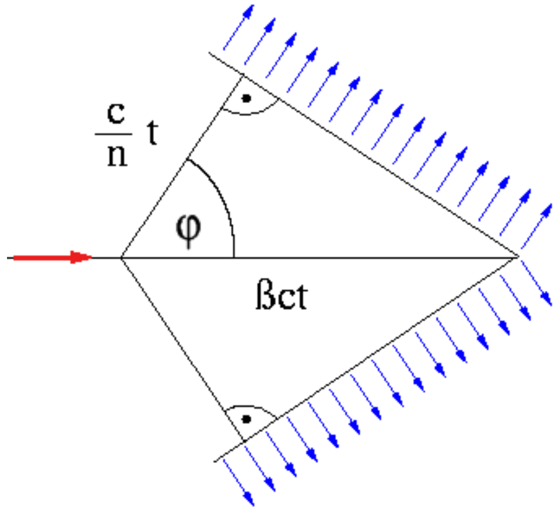


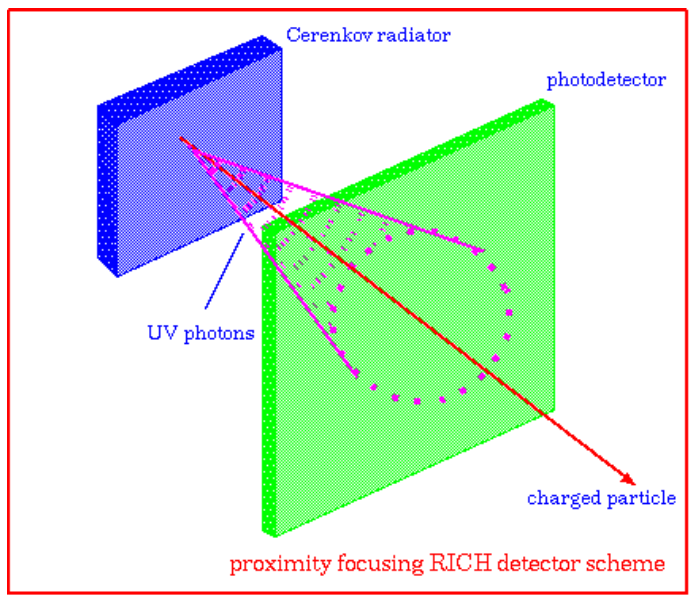
$$\cos\phi = \frac{1}{n\beta}$$

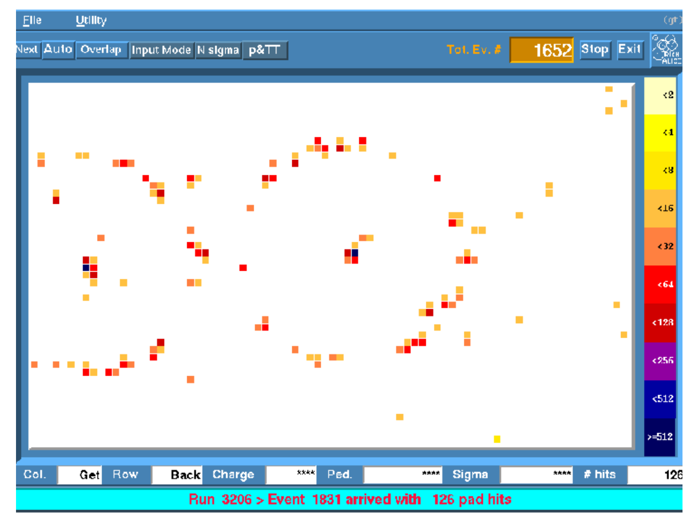
ϕ=42° at c in water

n is the dielectric refractive index, α = 1/137
x is the path length in radiator
e^- ~390 photons/cm in water (at 300-700 nm)

$$\frac{dN}{d\lambda} = \frac{2\pi\alpha\, x}{c}\left(1 - \frac{1}{n^2\beta^2}\right)\frac{1}{\lambda^2}$$

Ring Imaging Cherenkov detector uses a "thin" radiator to form a pulse of light emitted like a smoke ring that is detected downstream.

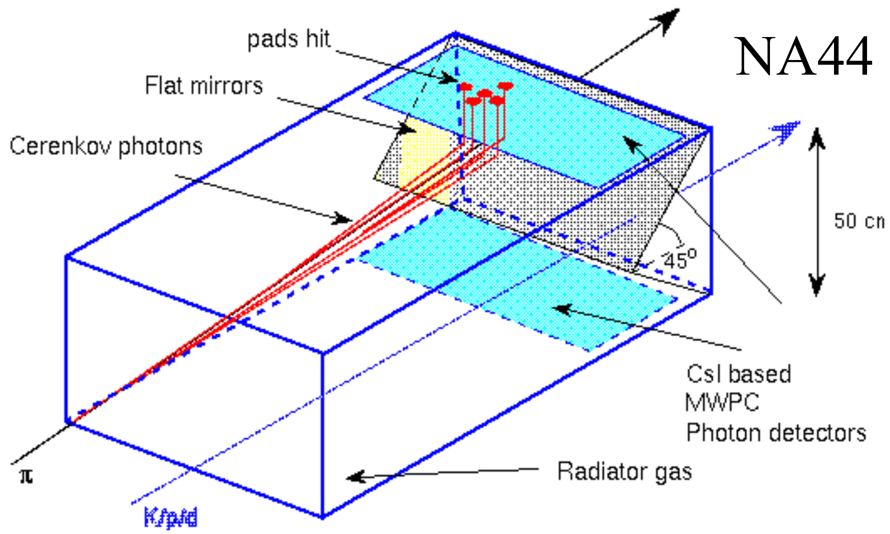




Miscellaneous Detectors: RICh's

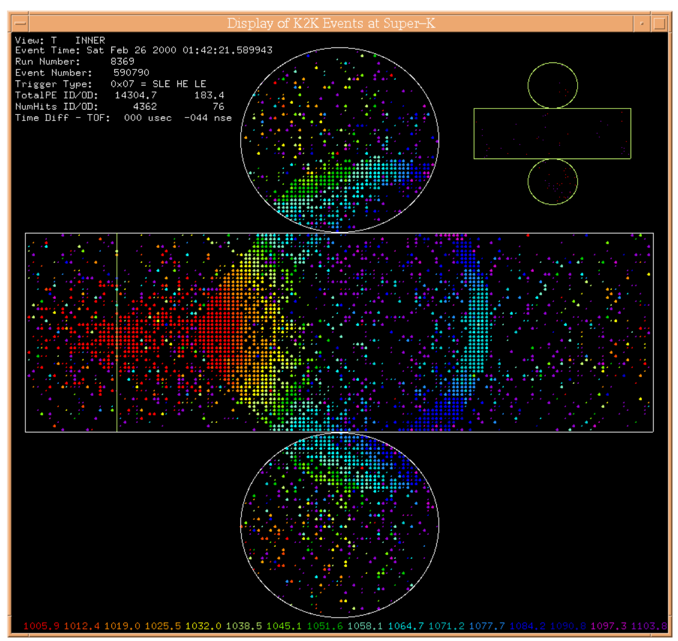
RICh detectors .. Many schemes in the high energy field

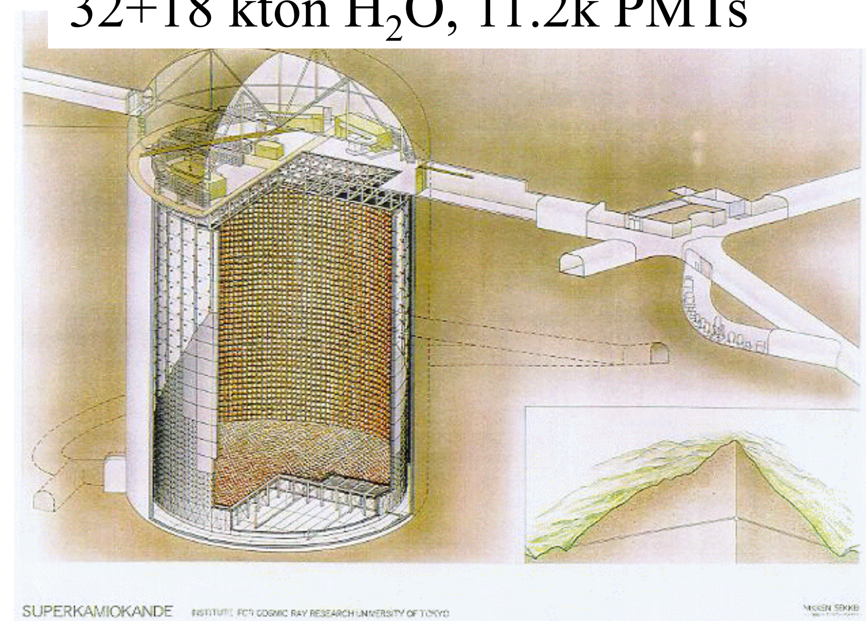
NA44 at Cern



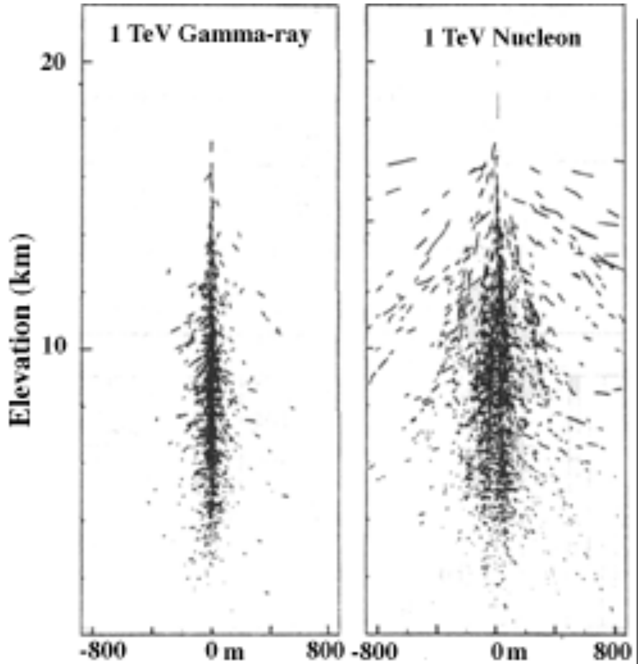
Schematic view of the detector

Super-K in Japan, 1km underground
32+18 kton H_2O, 11.2k PMTs

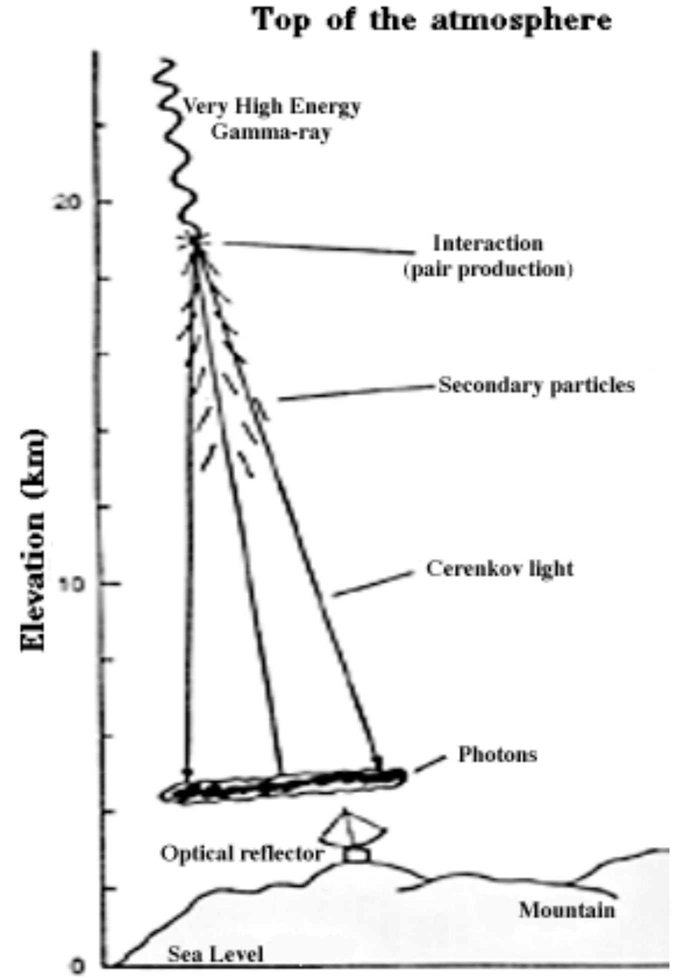




Miscellaneous Detectors: Air-Cerenkov Detectors



Extremely high energy γ-ray from space pair-produces at the top of the atmosphere and creates a characteristic shower of secondaries.



MAGIC at MPI-Munich
236 m^2 for cosmic rays

List of websites for various experiments:
http://www.mpi-hd.mpg.de/hfm/CosmicRay/CosmicRaySites.html

Misc. Dets. – Cloud & Bubble Chambers

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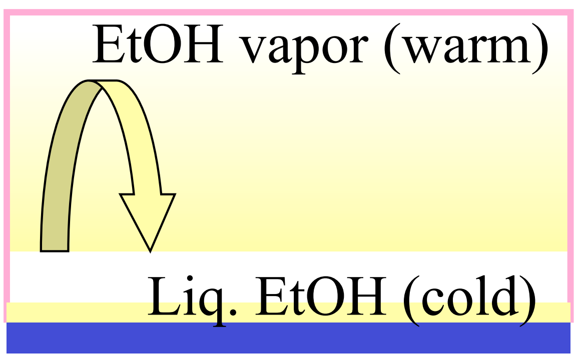
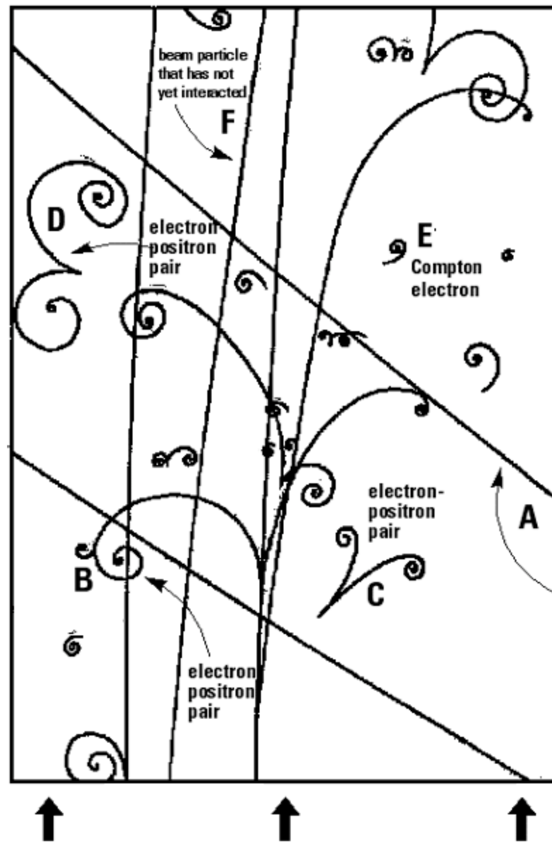
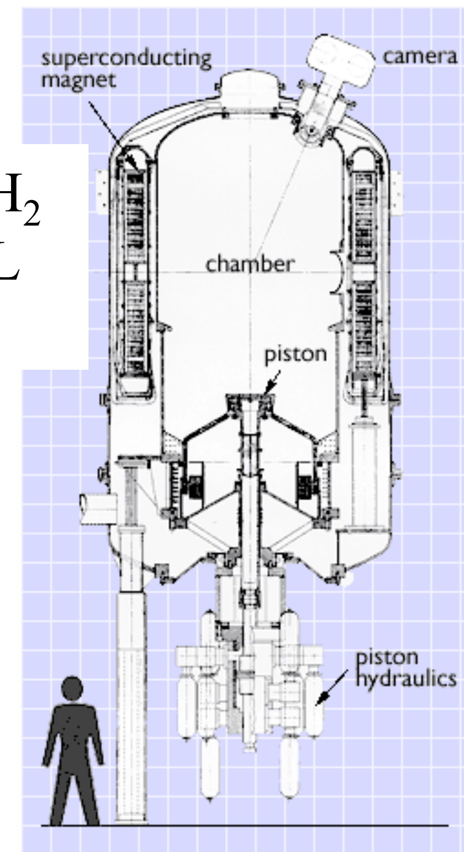
Cloud chambers were first developed by Charles T.R. Wilson around 1911 for experiments on the formation of rain clouds. The supersaturated water vapour condensed around ions created by dE/dx of radiation passing through the vapor. The difficulty is only in creating the supersaturation (vapor cooled below its boiling point).
Bubble chambers were developed by Donald Glaser (at UoM) based on the same principle but operating on superheated liquids like hydrogen and freons.



Cold Surface



7’ liq. H_2
At BNL
1974



Miscellaneous Detectors: Liquid Ion-Chambers

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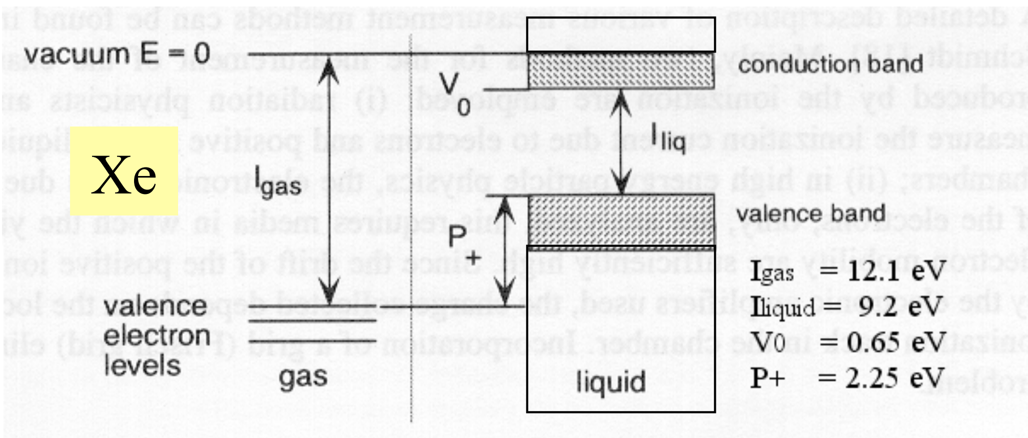
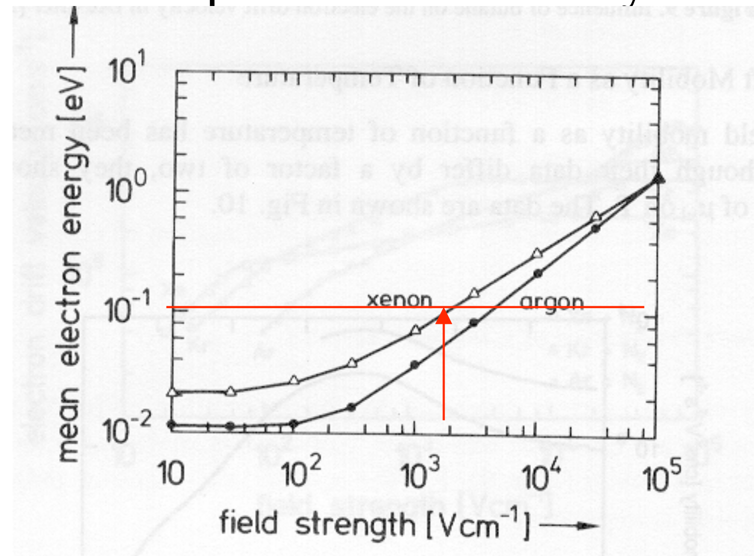
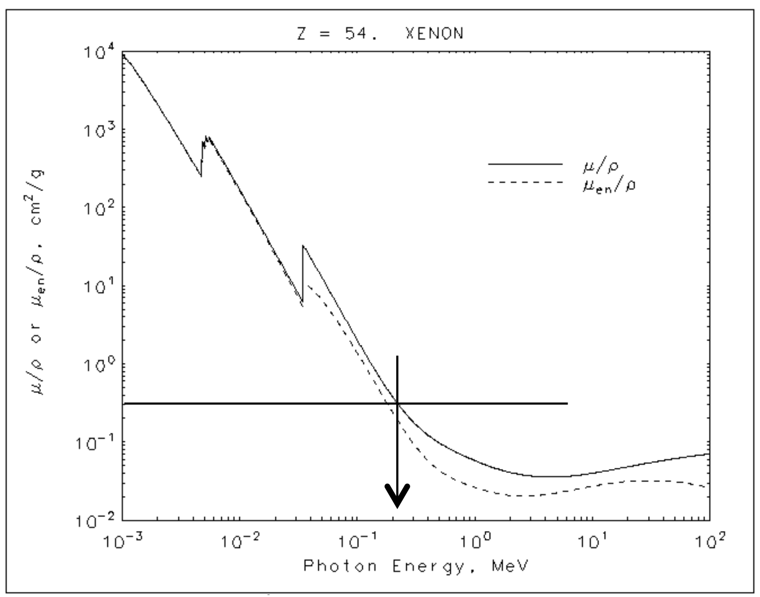
Liquid noble gases, particularly Xe (highest density, lowest FIP) and Ar (readily available) have been tested as ionization media. Overall, the charge carrier mobility is so low that the electrons are lost to impurities before they can be collected …







$$KE \sim 0.1eV \rightarrow v \sim \sqrt{\frac{2KE}{m}} \rightarrow \beta = \sqrt{\frac{2*0.1}{511x10^3}} = 6x10^{-4}$$

$$\sim 2x10^5\,cm/s \quad vis. \quad 10^7\,cm/s\ in\ Si\ and\ Ge$$

Try scintillation: pure liq-Xe scintillates at 178 nm (6.93 eV) with 61k photons/MeV , $\rho = 2.953$ g/cm^3 … $\mu \sim 1$cm at 0.2 MeV

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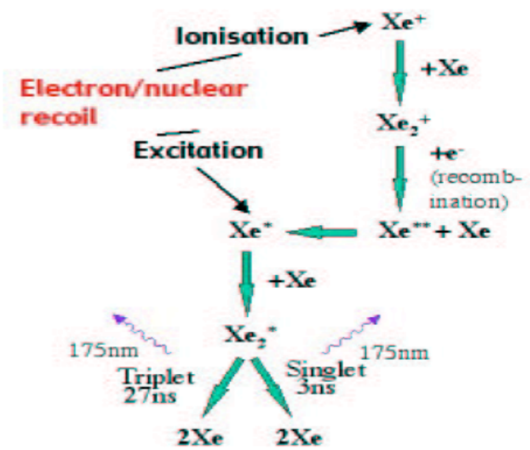


Miscellaneous Detectors: Bolometer

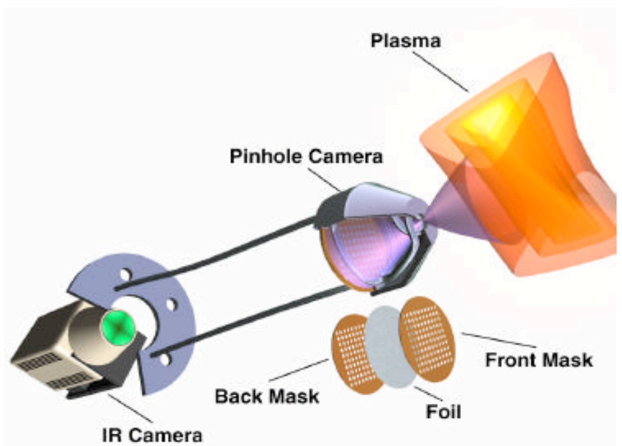
One can measure the energy itself through a temperature rise in a calorimeter – the energy is tiny, the heat capacity has to be tiny to be visible.

$$q = Cm\Delta T$$

C, the heat capacity, ~ T^3 at cryogenic temperatures

Room temperature devices are used in plasma physics with sensitivities on the order of 1μW/cm^2 and a time constant of 10ms.

$$q = 10^{-6} W\ 0.01 s = 10^{-8} J \quad \rightarrow \quad 70.x10^{9} eV$$



(100MeV/A ^{78}Kr is 8GeV)

The devices are very slow and thus have a large deadtime. They completely lack any discrimination, but they can be extremely efficient and are used in searches for exotica in nuclear and particle physics.

Miscellaneous Detectors: TLD Question

A TLD is a solid crystal phosphor when exposed to radiation at normal temperature, electrons in the crystal structure are released and trapped in the crystal lattice defects (traps) in the structure producing a long-lived metastable energy state for the electrons. The electrons remained trapped for a long period of time. When the crystal is heated (200-400^{o}C), the electrons are released from the traps and return to their original ground state, emitting a photon. (Scintillation for rapid decay, phosphorescence for slow decay.) The number of photons is proportional to the number of electrons trapped, which in turn is proportional to the amount of radiation that was incident on the crystal. Materials include LiF and CaF … small chips with mm sizes Typical precision is ~15% at low doses dropping to ~3% at high doses.

Question: How many photons are emitted by the TLD device at low doses?