07 - Cherenkov and transition radiation detectors

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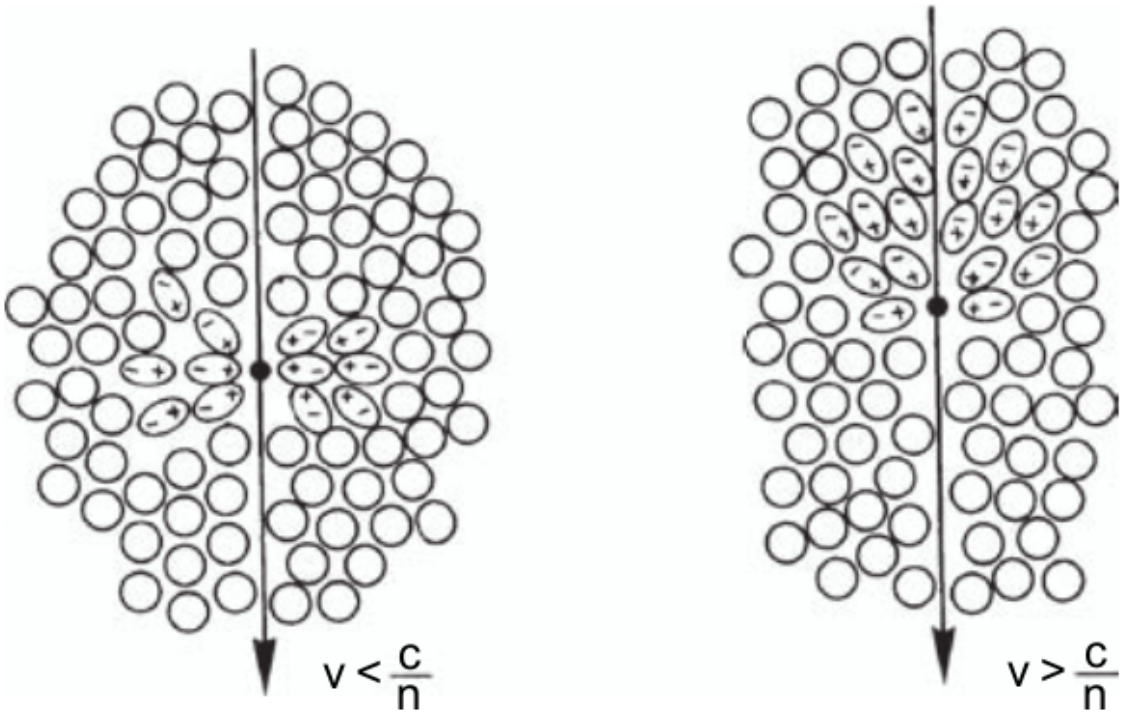
Version 2

Cherenkov radiation

- Emitted by passage of charged particle in dielectricum at velocity greater than speed of light in respective material
- $\beta > 1/n$ where n is refractive index
- Dipole moment of polarized electrons, emission of electromagnetic field

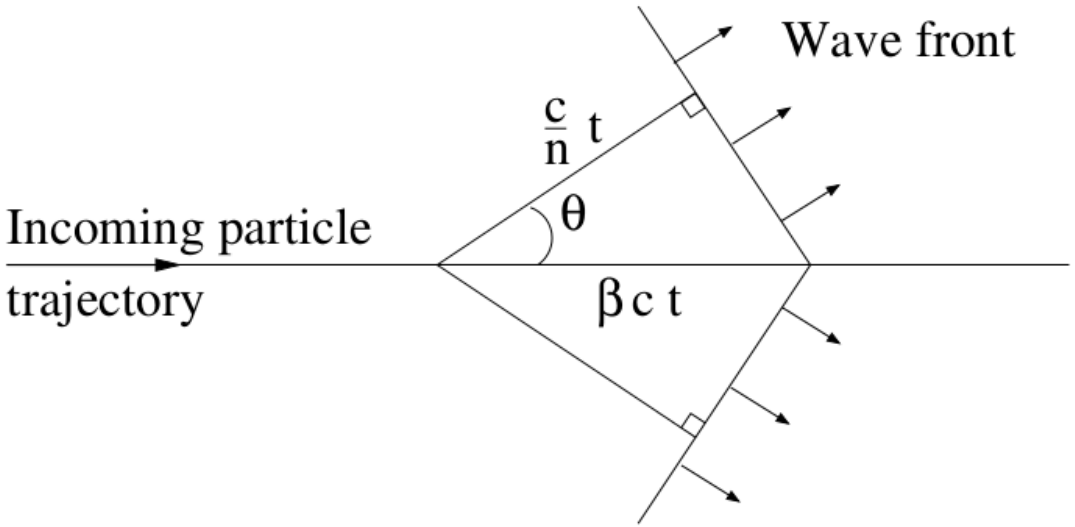


Angle of Cherenkov radiation emission

- Light emitted into forward cone of aperture

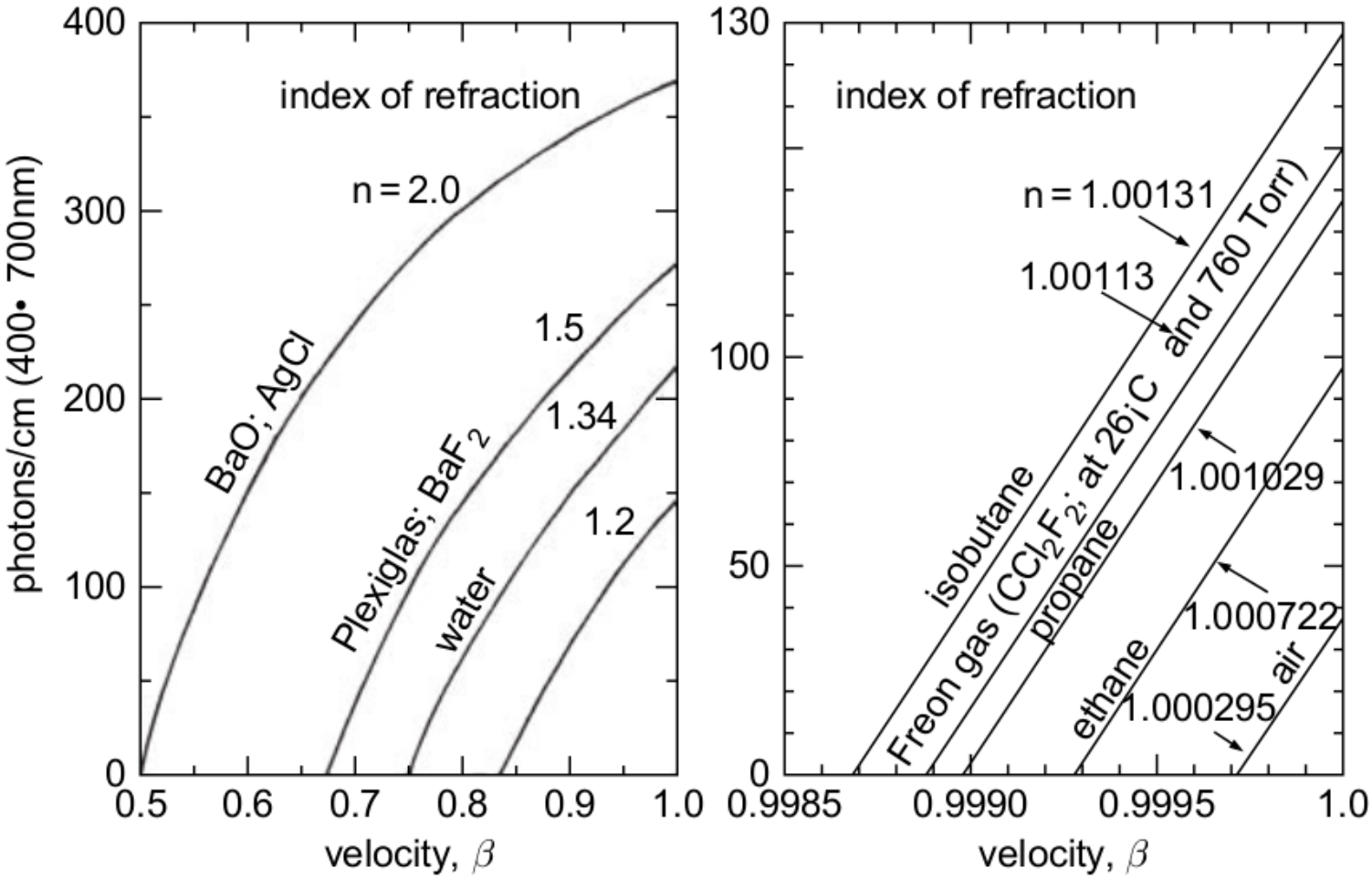
$$\cos\theta = \frac{1}{\beta n} \tag{1}$$

- Threshold of Cherenkov light emission given by $\beta_{thr} \geq \frac{1}{n}$



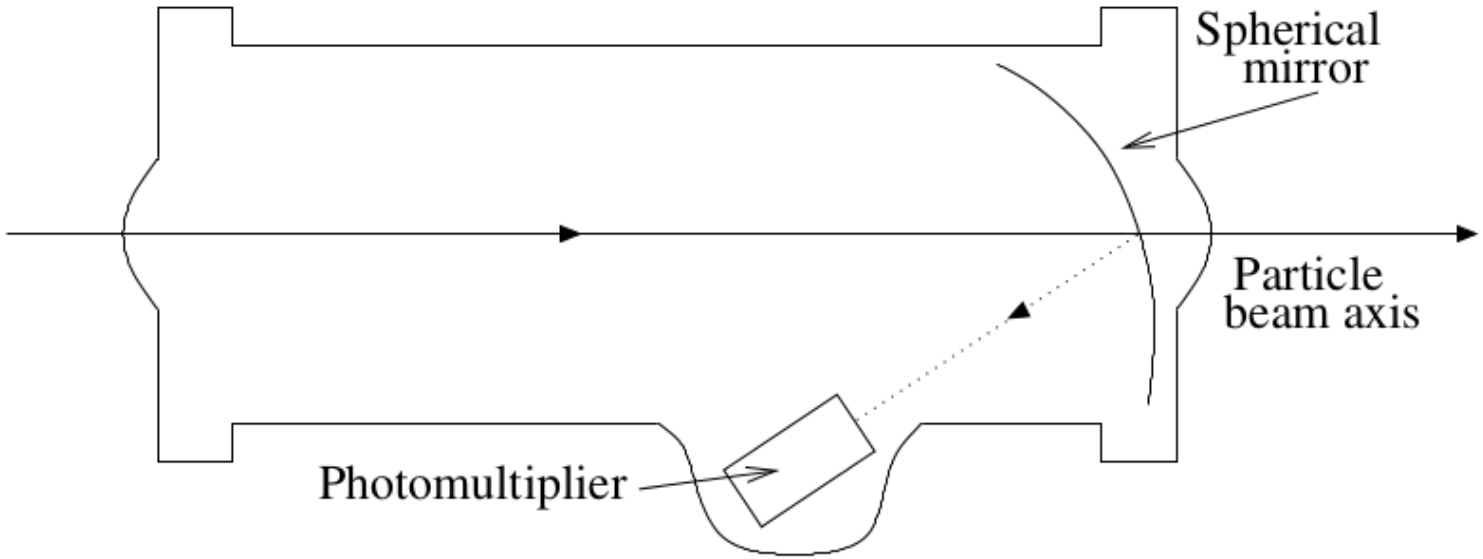
Yield of Cherenkov photons

- Yield per unit length of track proportional to λ^{-2}
- Smaller than scintillation light

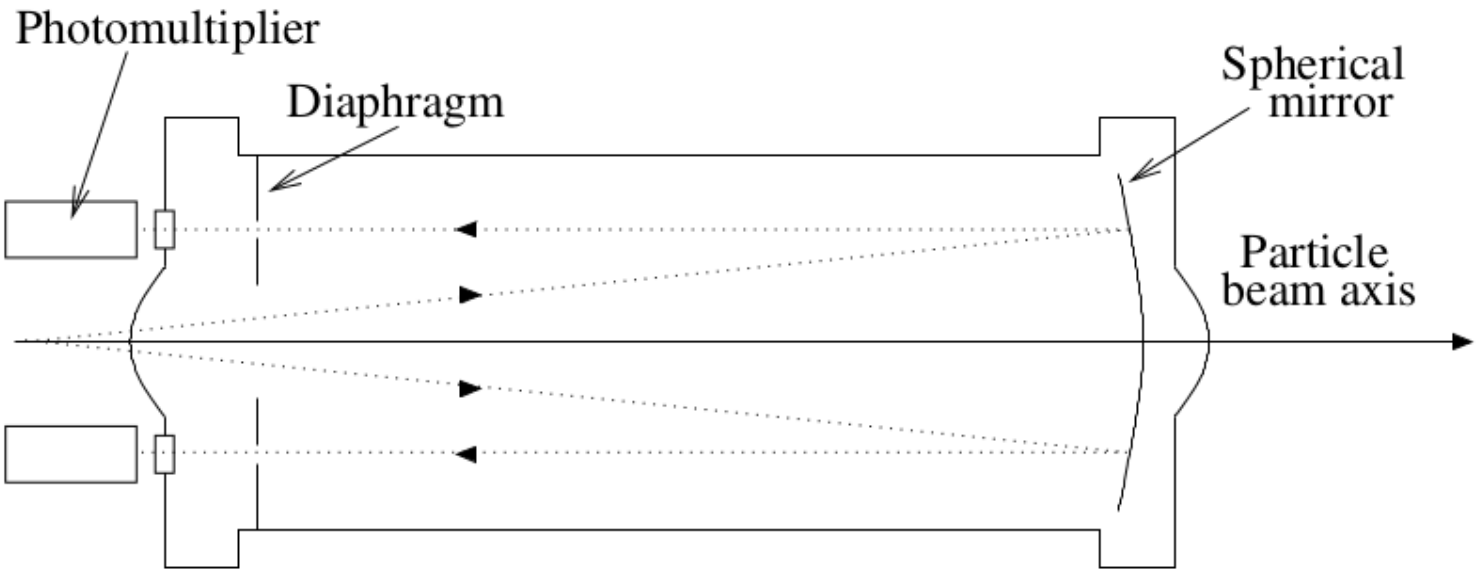


Threshold Cherenkov detectors

- Separation of particles with different masses at the same momentum
- Set of Cherenkov radiators of different n, different threshold for each particle
- Radiators of material of desired n or gaseous radiator at a given pressure

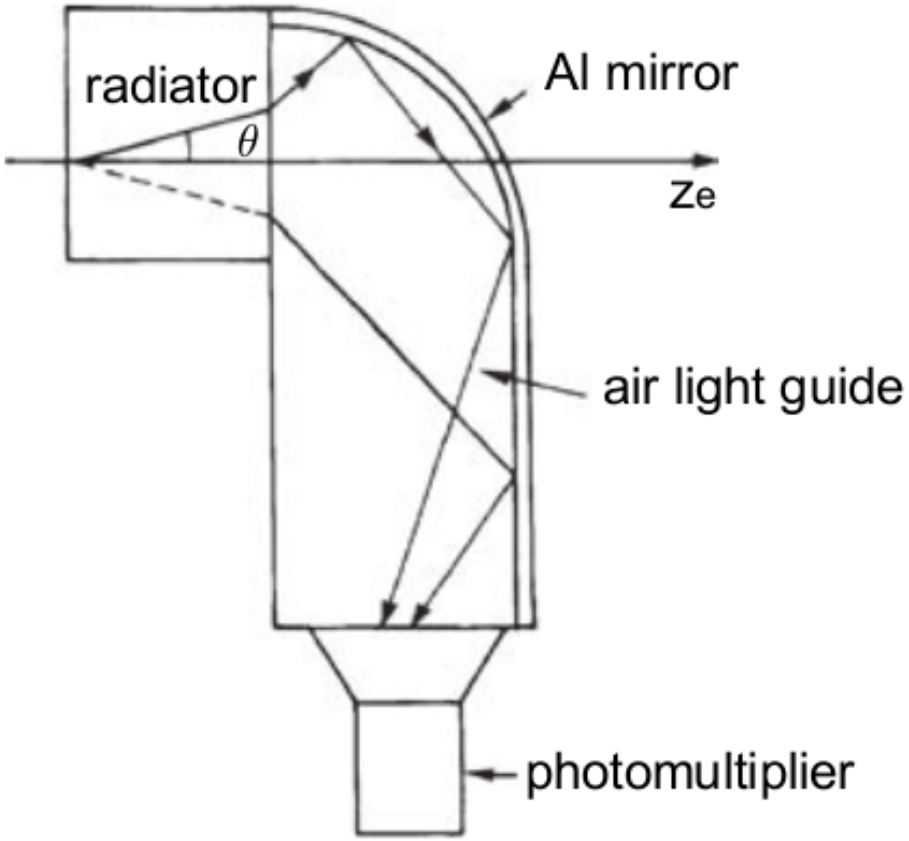


Differential Cherenkov detectors



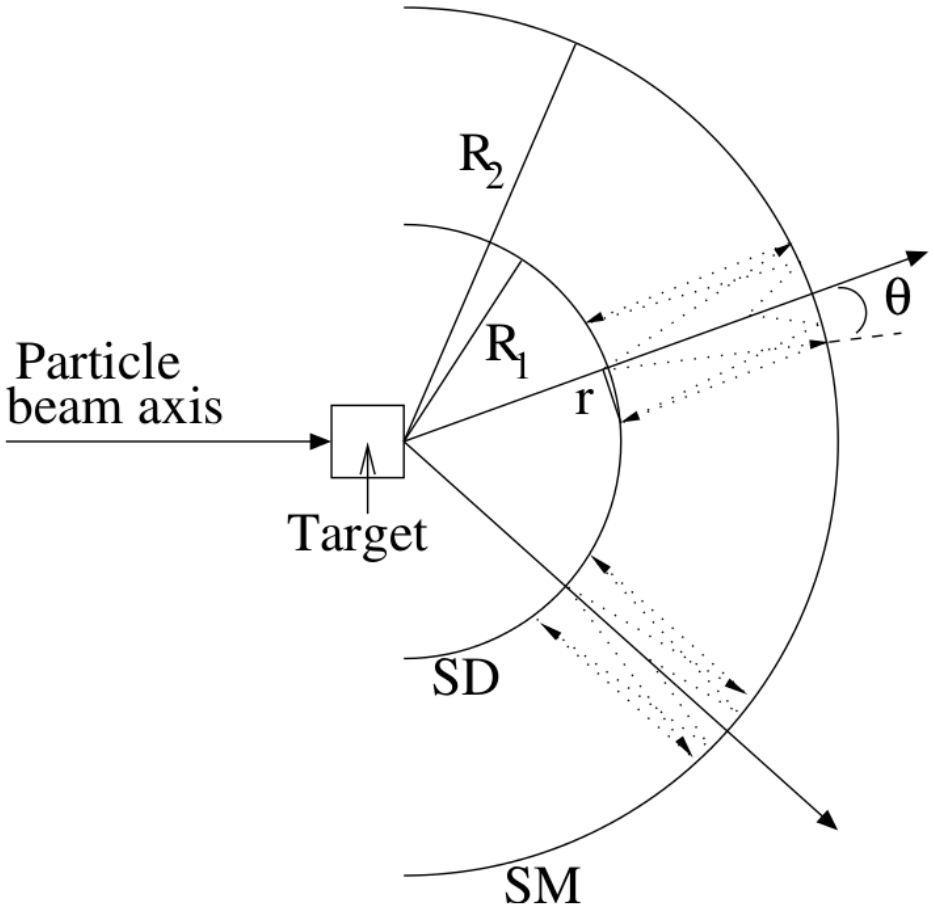
- Tagging of particles in selected range of velocities
- Light reflected by spherical mirror, aperture in front of PM provides velocity window
- Particles parallel to optical axis (fixed-target experiments)

Fitch-type differential Cherenkov detector



- Upper limit on velocity by internal reflection
- Light at higher angle does not escape into the light guide

Ring imaging Cherenkov (RICH) detector



- Particle identification by angle of Cherenkov radiation
- Photons reflected by spherical mirror (SM) and focused onto spherical detector SD
- Measured circle of Cherenkov photons to get particle velocity, together with particle momentum provides the identification

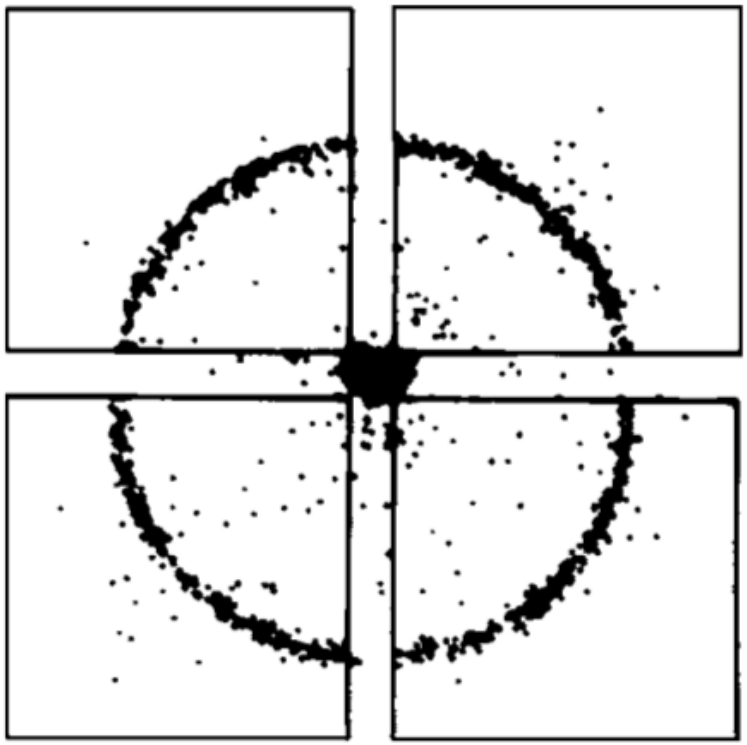
Detection of Cherenkov photons in RICH

- Position sensitive detector of large surface
- MWPC with photosensitive vapor in counter gas
- Quartz entrance window for vapor of low ionization energy, UV transparent crystal otherwise
- More intense rings by fast heavy ions (number of photons proportional to square of particle charge)

Cherenkov ring of relativistic heavy ion in RICH

- Early measurement of heavy ion with RICH
- Center of ring visible due to ionization loss in photon detector
- Spurious signals by δ-rays of heavy ion

Cherenkov rings by monoenergetic beam

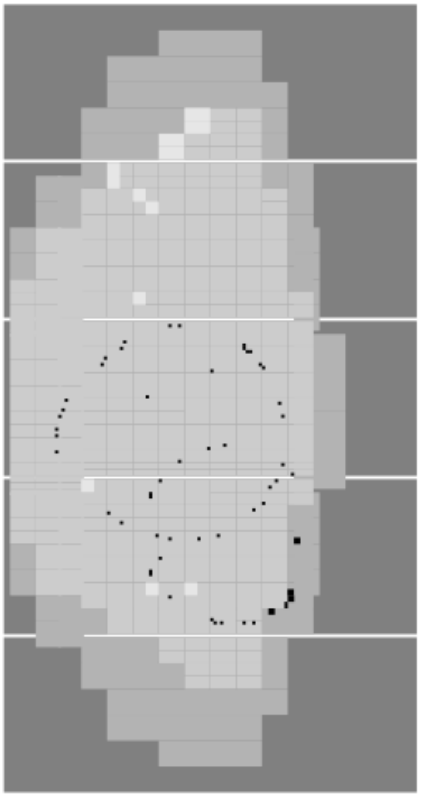


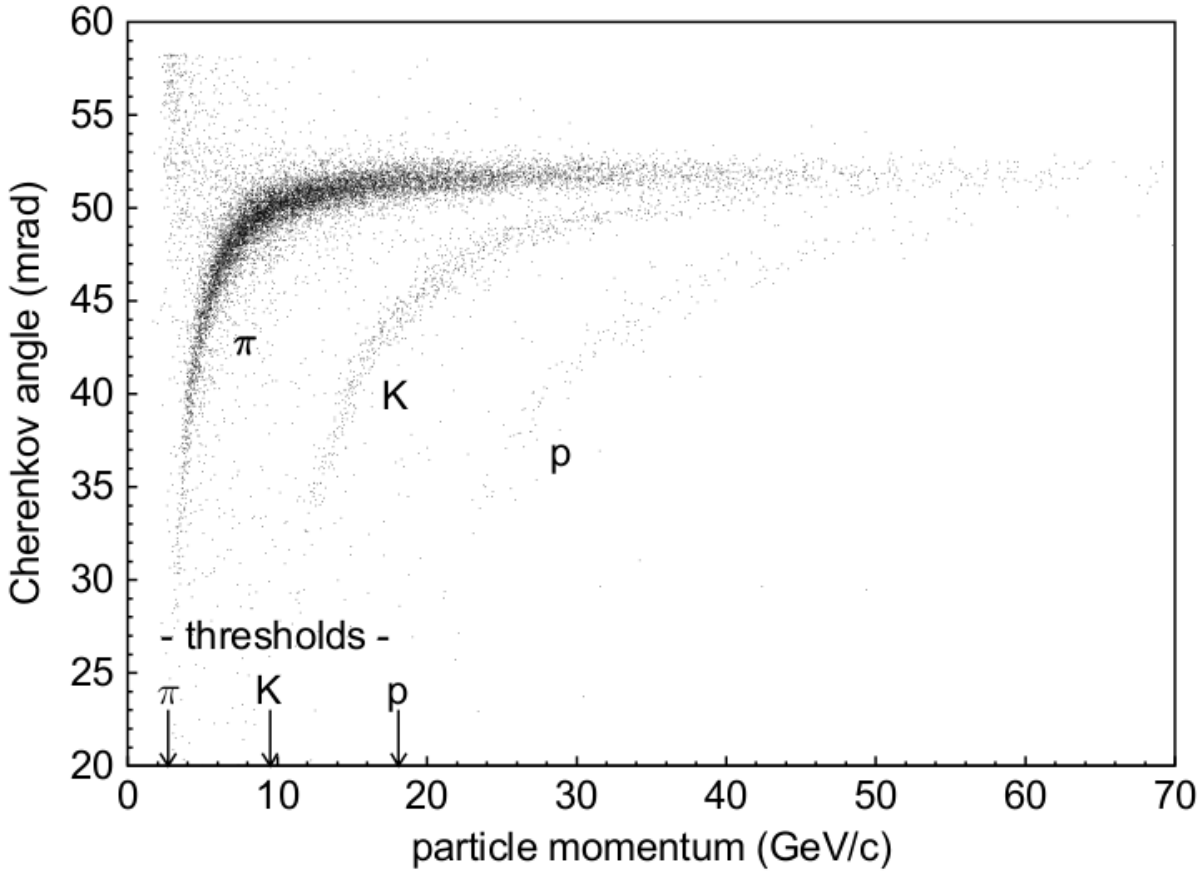
- 100 events of collinear monoenergetic beam
- Entrance windows by calcium-fluoride crystals

Solid-state detectors in RICH

- CsI photocathode as photoconverter
- Single or multi-anode conventional photomultiplier or hybrid photomultiplier
- Micropattern gaseous detector with CsI photocathode

Cherenkov angle dependence on particle momentum





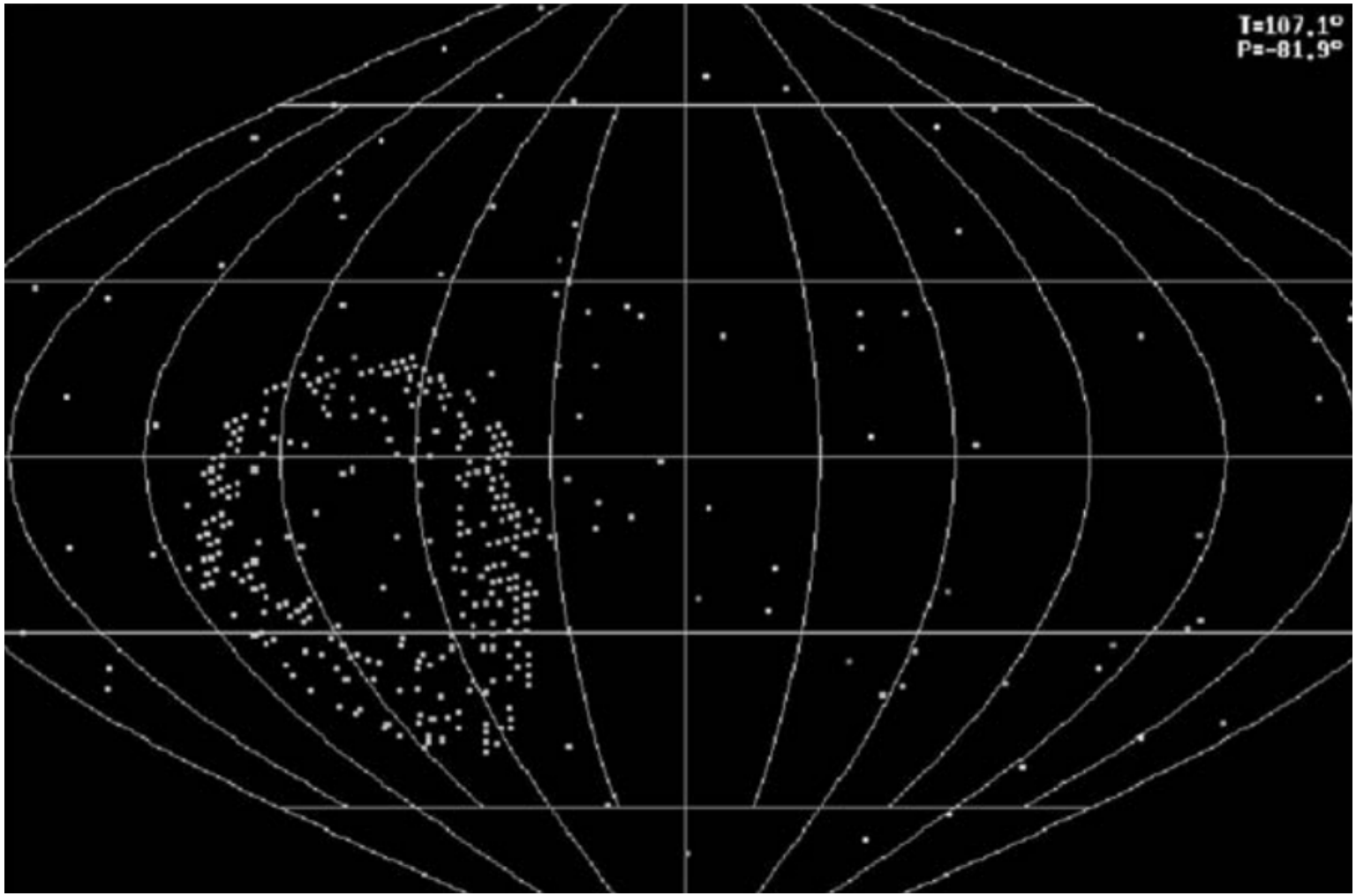
- Cherenkov rings detected by system of multichannel photomultipliers

Cherenkov rings in electromagnetic cascades

- Secondary particles in cascade follows direction of initiating electron or photon
- Also relativistic, emit overlapping Cherenkov rings, concentric with equal radii
- Distortion of the ring (elliptic for inclined angle) gives direction of incidence - gamma-ray astronomy

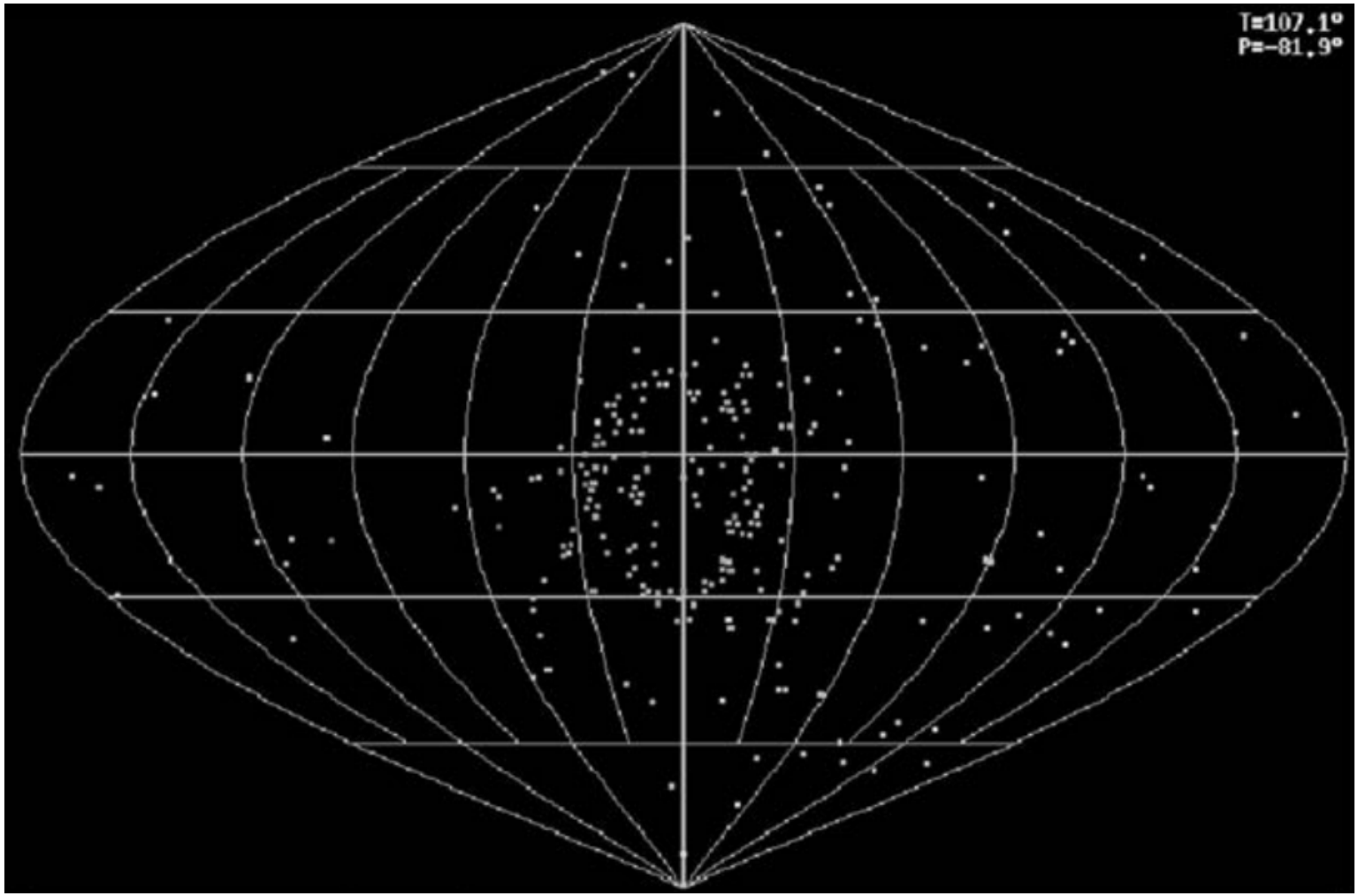
Detection of neutrino induced muons and electrons

- Muon produced in interaction of atmospheric neutrino, detected by Cherenkov ring in heavy water

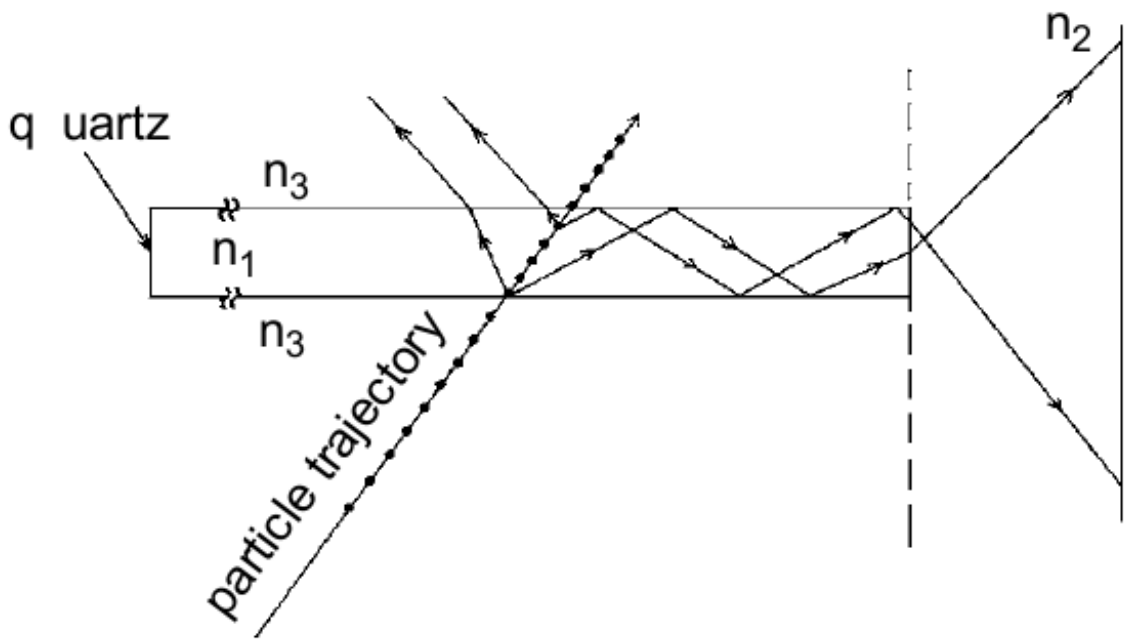


Detection of neutrino induced muons and electrons

- Cherenkov ring of electron from decay of muon which was produced by neutrino interaction



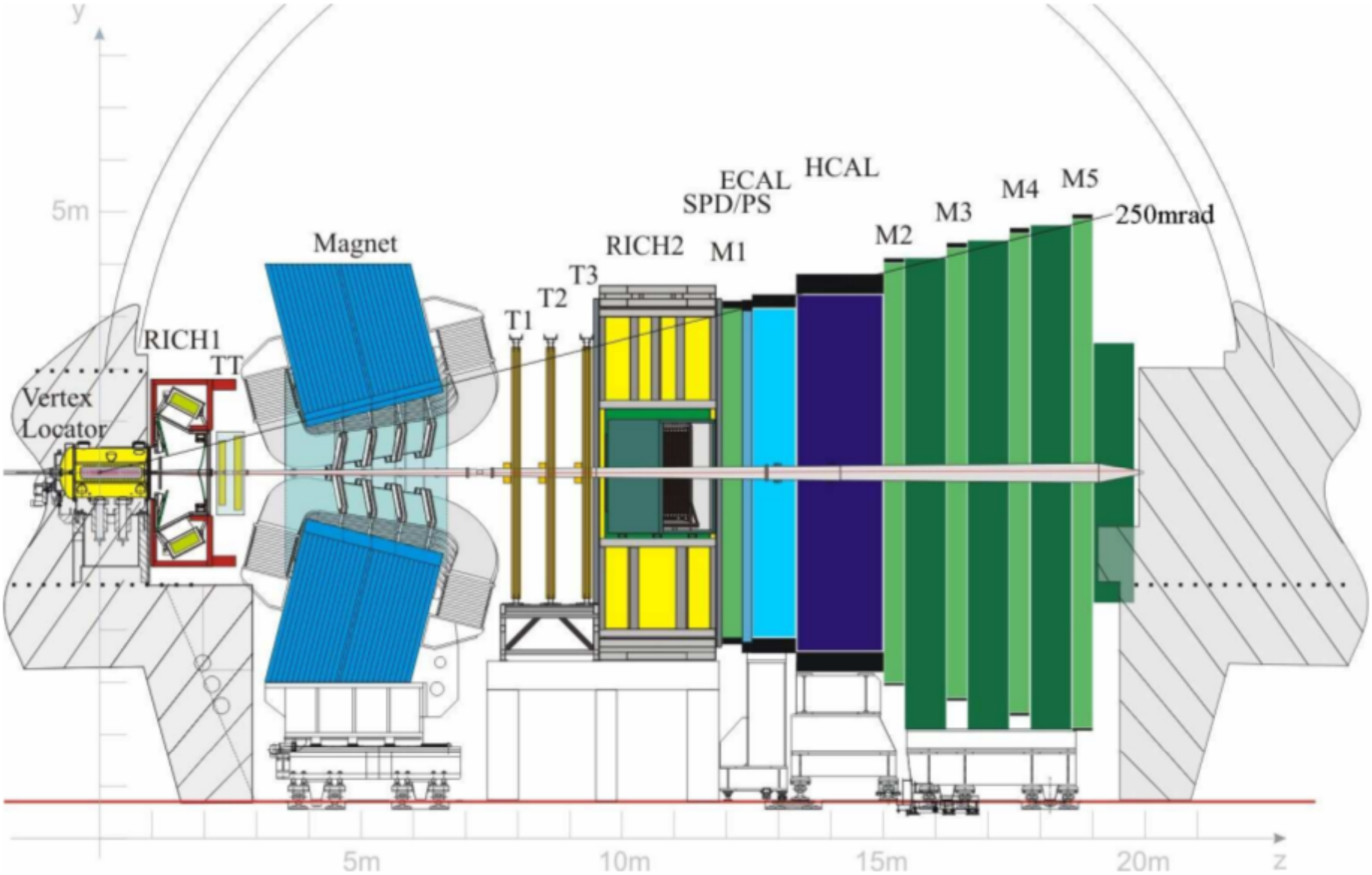
Detector of Internally Reflected Cherenkov light (DIRC)



- Based on internal reflection of Cherenkov radiation in quartz bars of rectangular cross section
- Readout by system of PM tubes

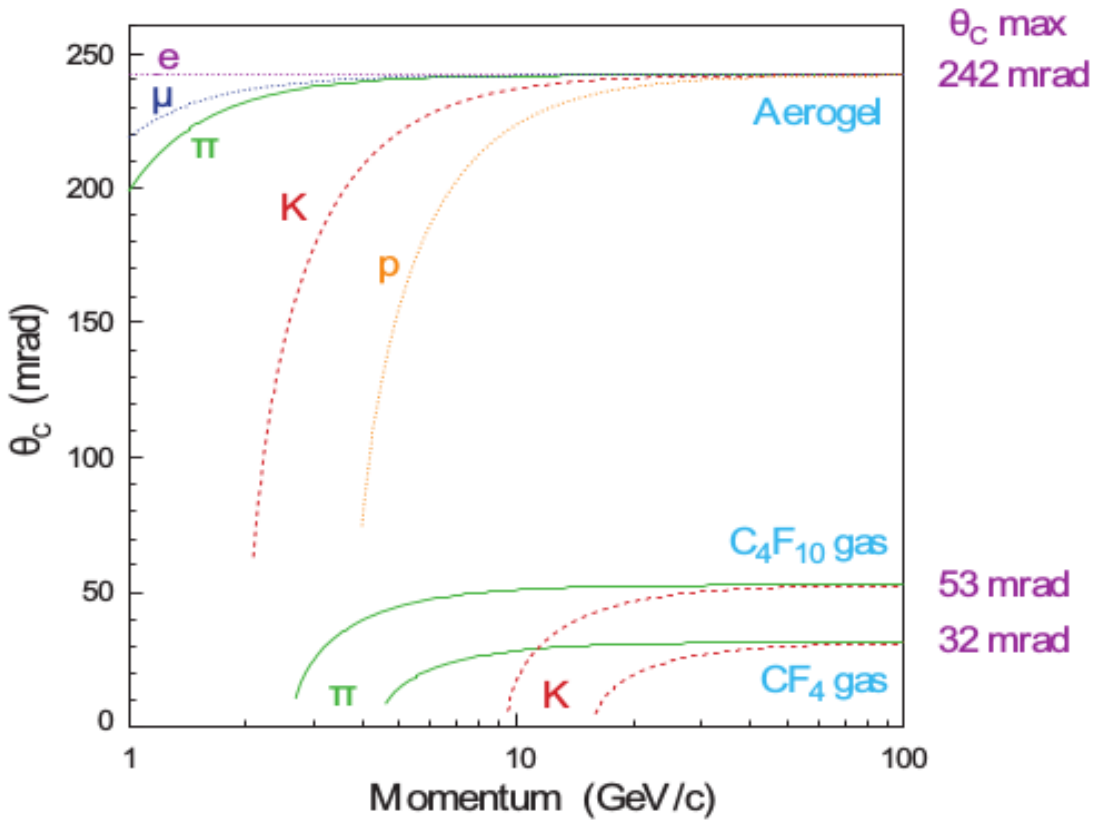
RICH of LHCb experiment

- Detectors RICH1 and RICH2



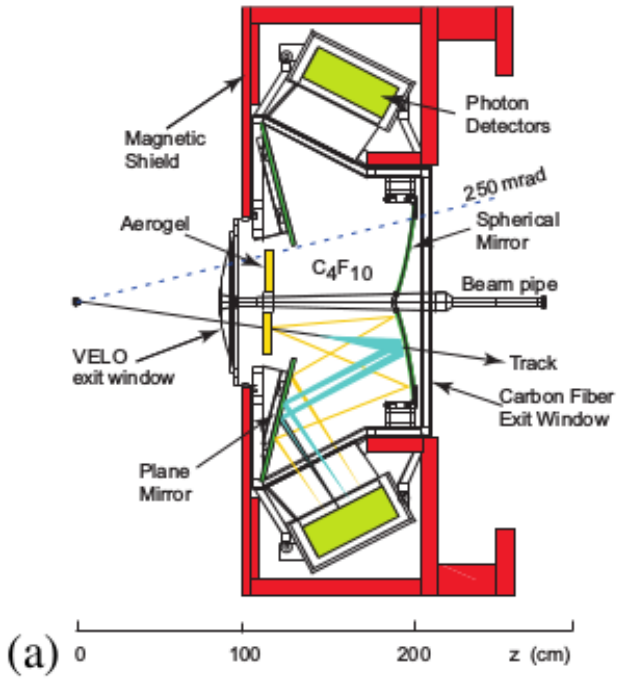
Cherenkov radiators of RICH in LHCb

- Different particle momenta covered by RICH1 (lower) and RICH2 (higher momentum)
- Identification among several particle species

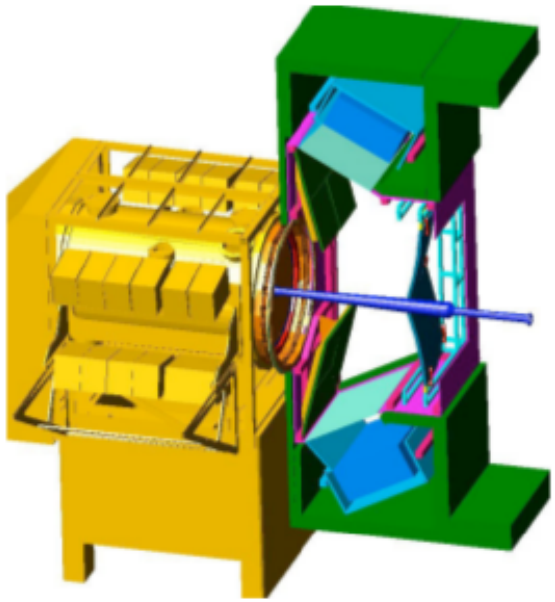


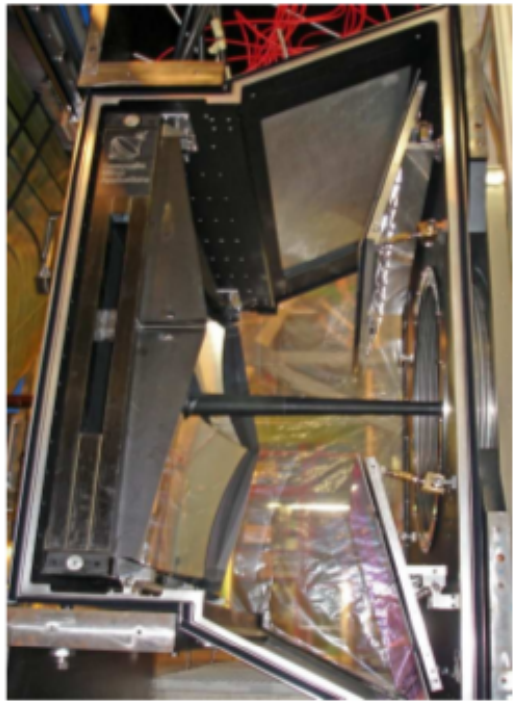
Layout of RICH1 in LHCb

- Cherenkov light emitted by Aerogel and gaseous radiators
- Light reflected by flat and spherical mirrors outside the LHCb acceptance



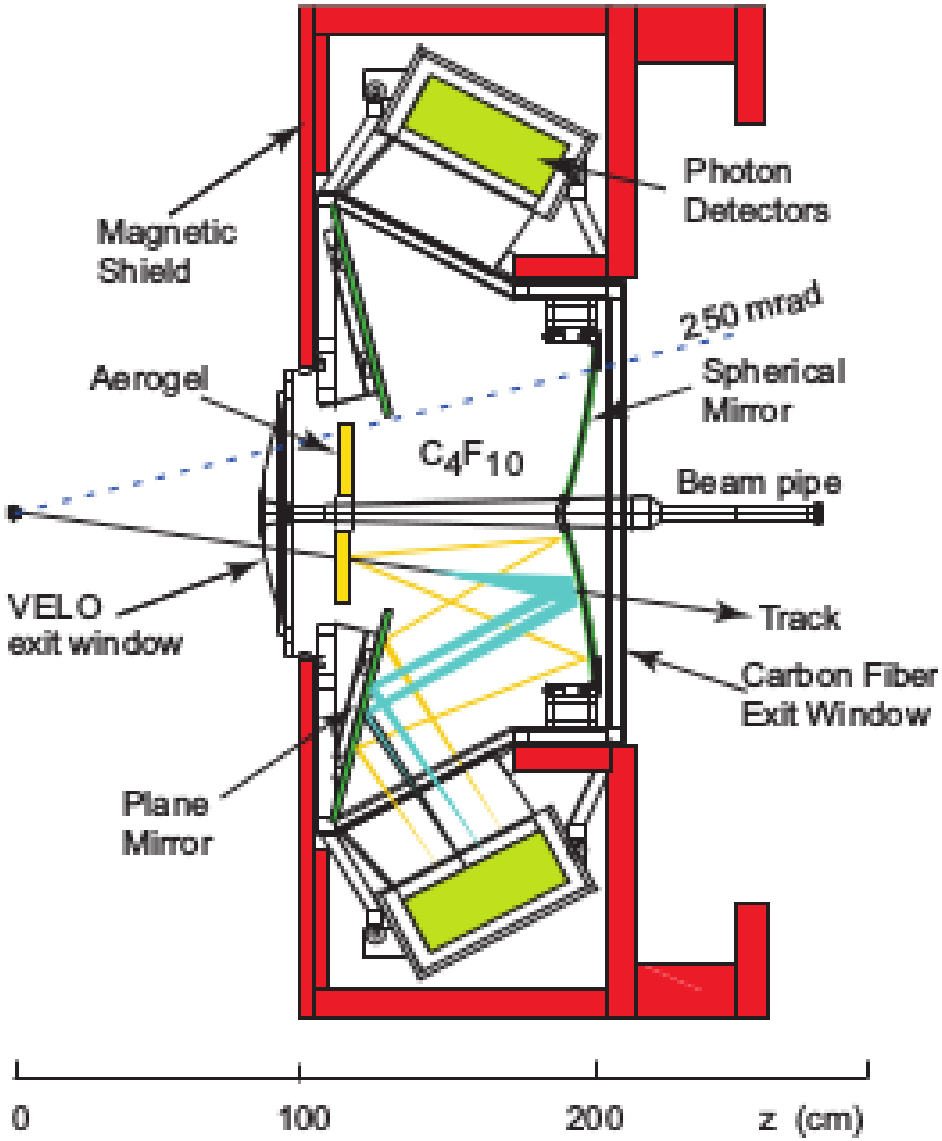
(a)


(b)


(c)

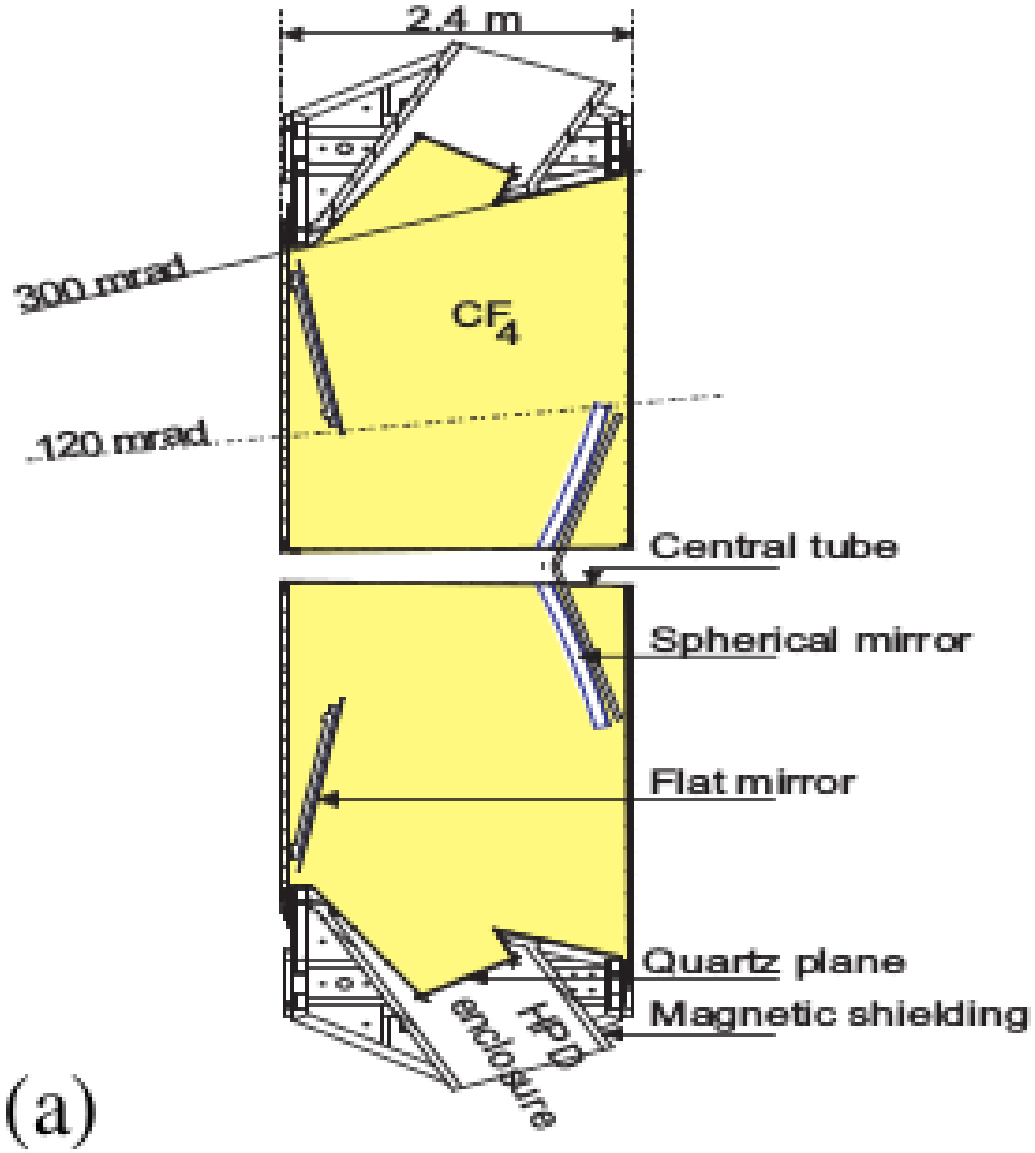
Layout of RICH1 in LHCb

- Reflected Cherenkov light detected by the photon detectors



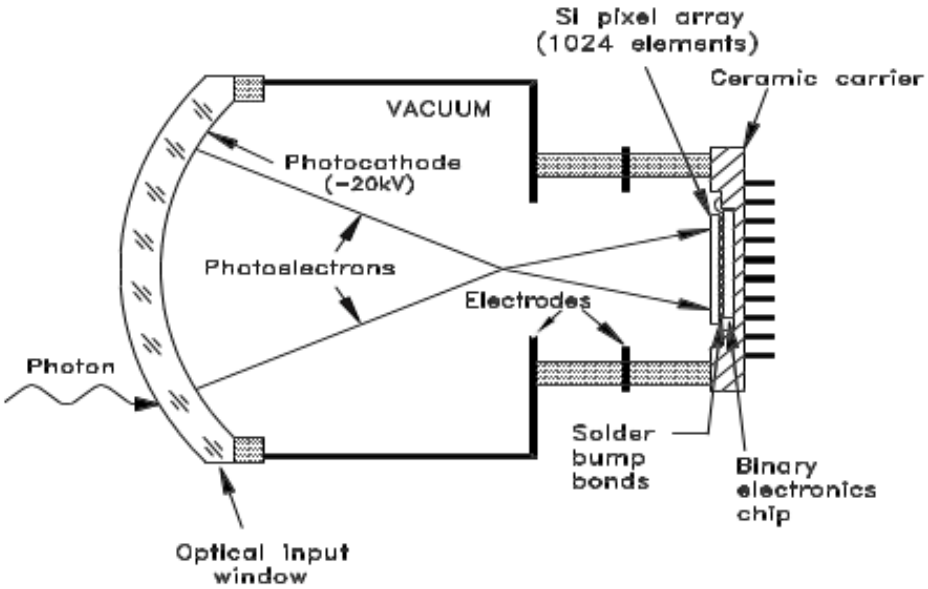
Layout of RICH2 in LHCb

- Second Cherenkov detector with different radiator



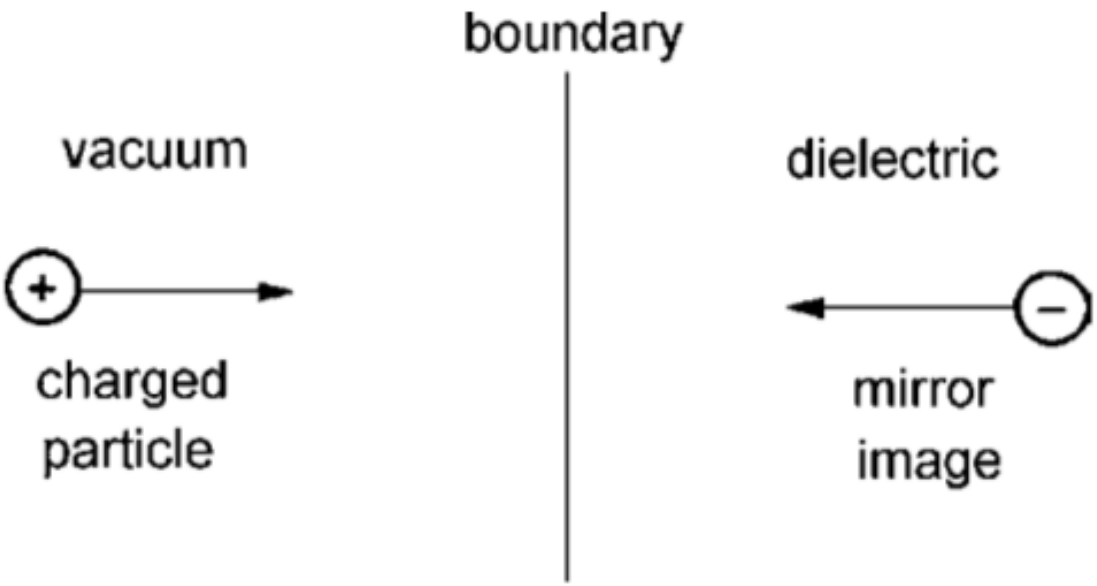
Photon detector in RICH of LHCb

- Hybrid photon detector HPD
- Photon conversion at photocathode, photoelectron accelerated and detected by segmented silicon detector
- Image of photocathode de-magnified onto the detector by the electrodes



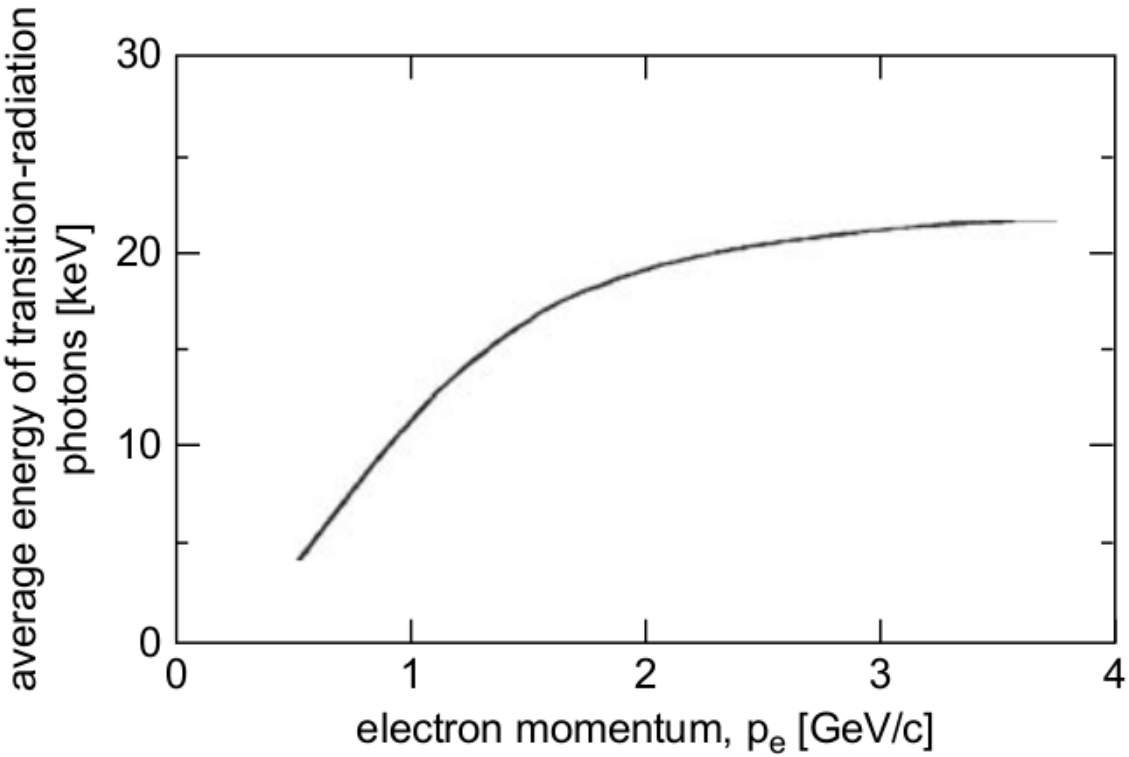
Transition radiation detectors (TRD)

- Charged particle moving towards boundaty of materials of different dielectric properties
- Time-dependent electromagnetic field of electric dipole of charged particle and it's mirror at boundary
- Emission of electromagnetic radiation



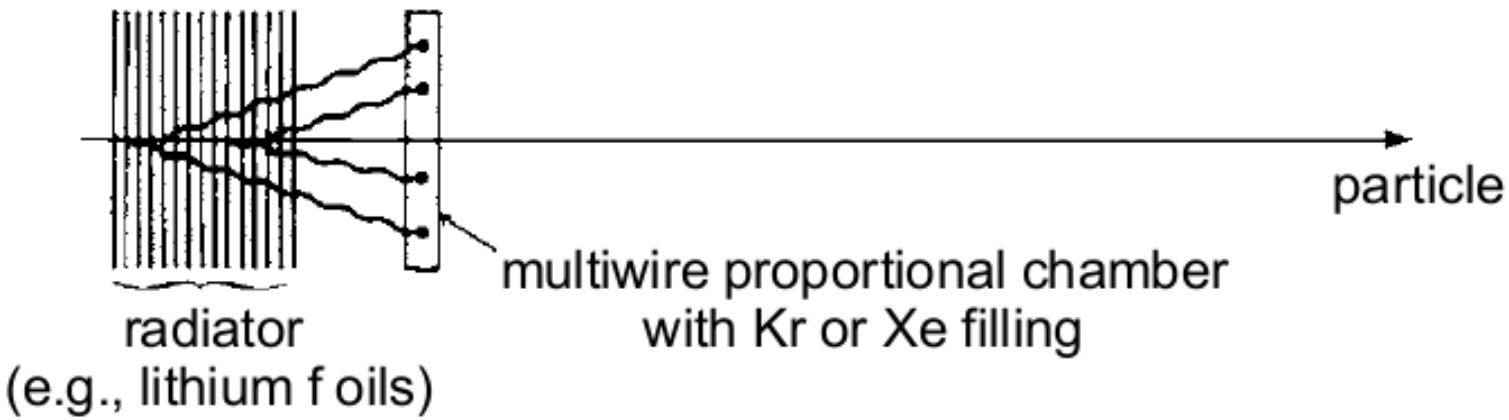
Energy of transition-radiation photons

- Average energy of TRD photons vs. electron momentum



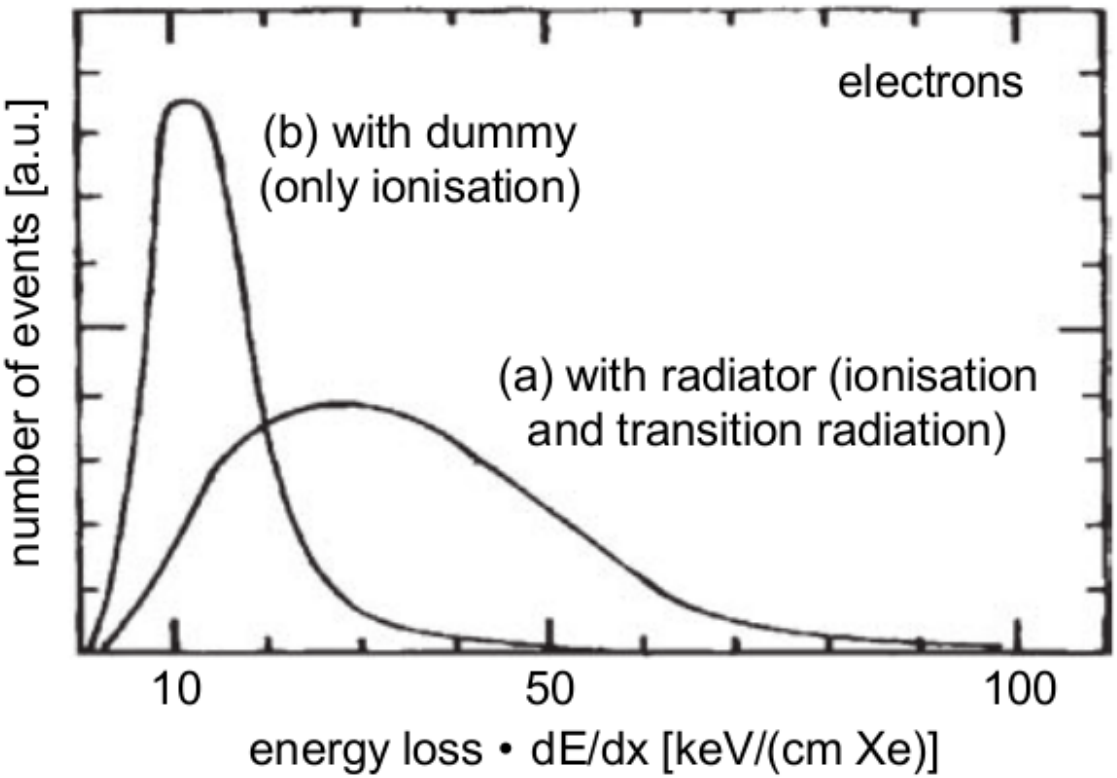
Arrangement of transition-radiation detector

- Angle of emission of transition-radiation photons inversely proportional to Lorentz factor of the particle
- System of periodic foils and gaps as radiator
- Photons detected by MWPC filled by Kr or Xe



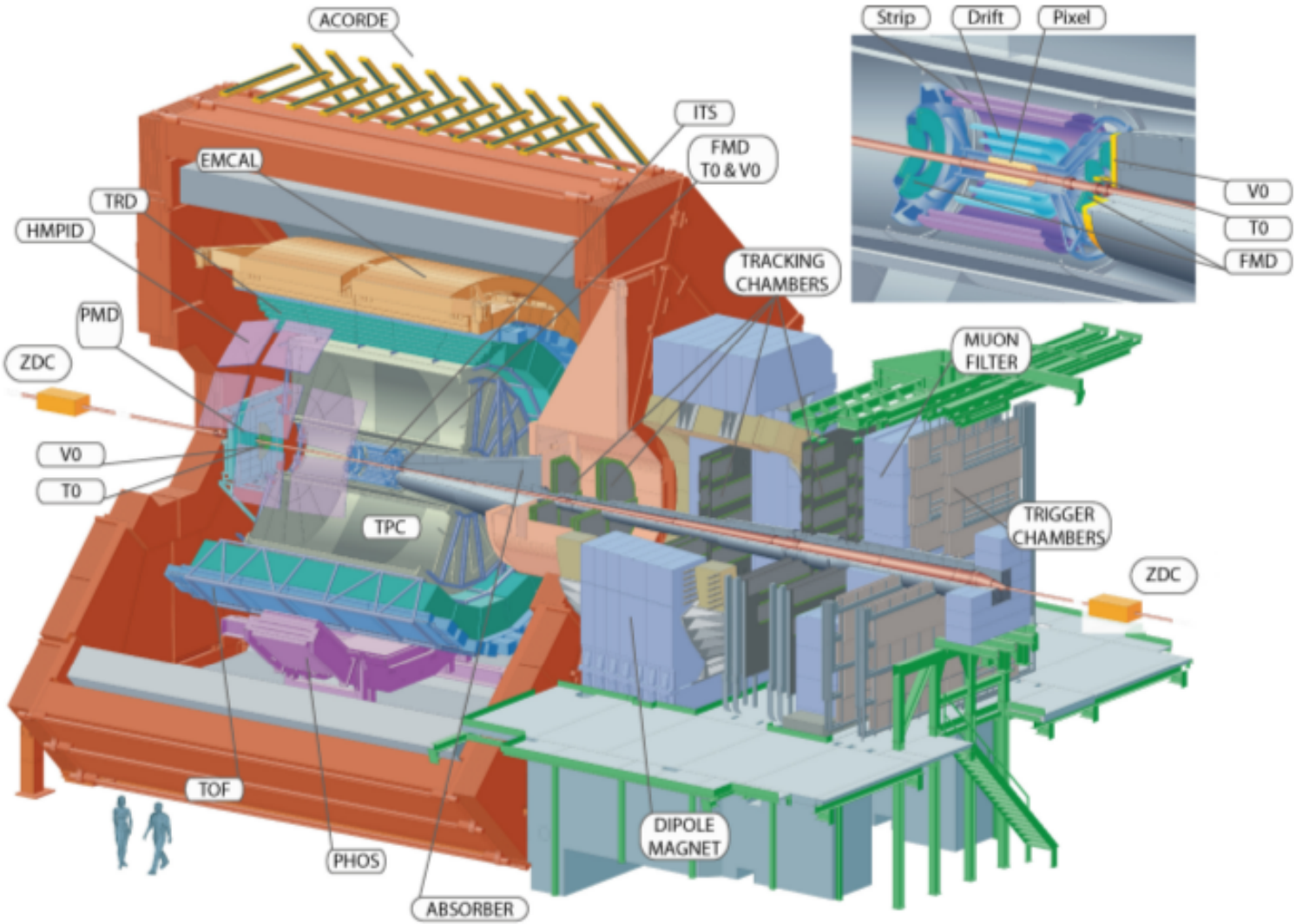
Energy loss distribution in TRD

- Energy loss by relativistic electrons
- (a) - radiator with gaps, (b) - radiator without gaps, no transition radiation in this case



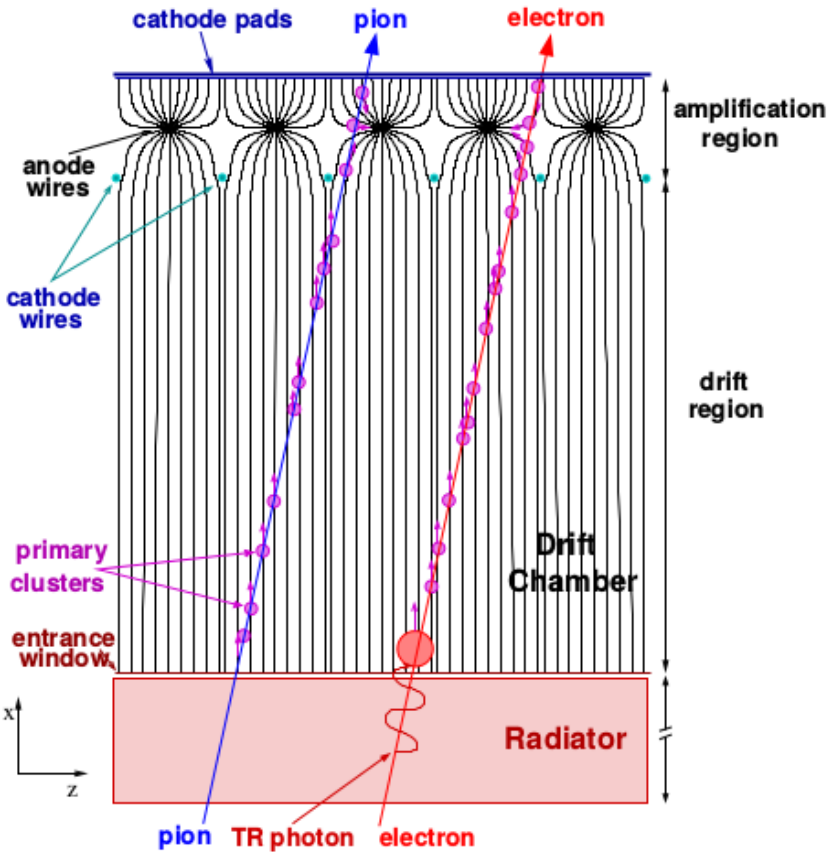
TRD of ALICE experiment

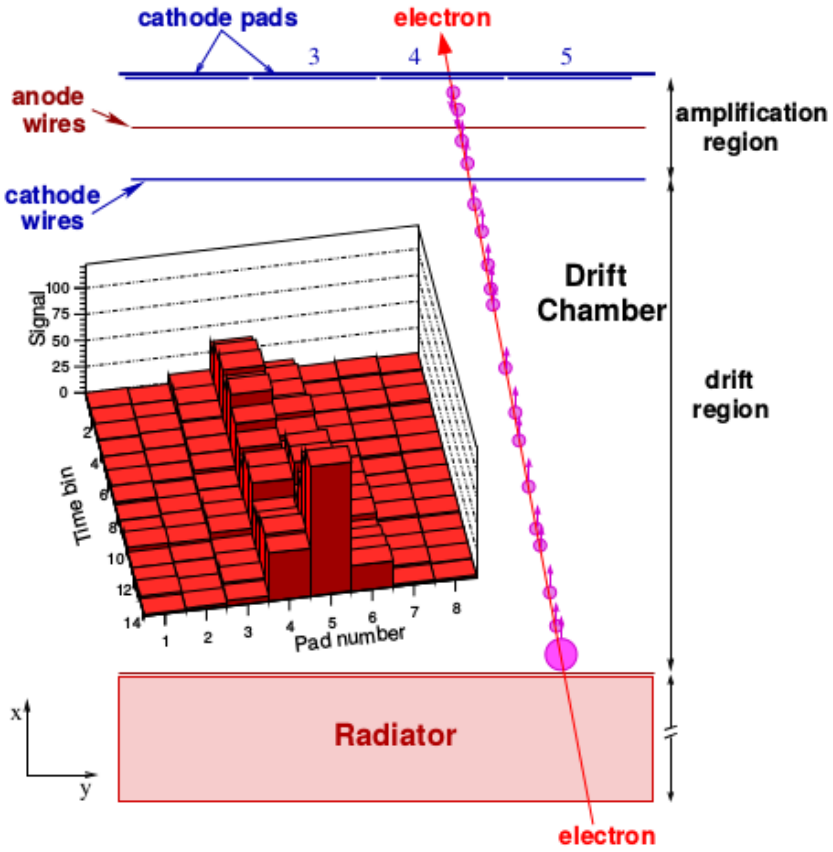
- TRD located in the central barrel above TPC, provides electron identification



Detector element of TRD in ALICE experiment

- Radiator for transition radiation, gas drift volume of Xe/CO_2 and MWPC
- X-ray photons of transition radiation converted at the beginning of drift volume





Electron identification by TRD in ALICE

- Discrimination between electrons and pions
- Increased specific energy loss by electrons at the same momentum
- Signal at large drift times for electrons by conversion of transition radiation at the beginning of drift sector