Transition Radiation Detectors

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Transition Radiation Detectors

Devices utilizing transition radiation have proved useful for the detection of electrons and for particle identification at high energies.

- Radiated energy is $\propto \gamma$
- TR photons are emitted in the X-ray range.
- Threshold behaviour at a value of $\gamma \approx 1000$ for periodic arrangements of radiator material and gaps.

Transition Radiation

The sudden redistribution of charges in the medium associated with the changing electric field of the particle gives rise to the transition radiation.

The total energy emitted upon crossing a single surface is:

$$W = \frac{2}{3}\alpha\,\omega_p\,\gamma$$

where α is the fine structure constant and ω_p is the plasma frequency of the medium,

$$\omega_p^2 = \frac{4\pi\alpha Z N_A \rho}{A m_e} \simeq 2\,(Z/A)(\rho/\mathrm{g\ cm^{-3}})(21\ \mathrm{eV})^2$$

The mean number of X-rays emitted per surface and the angle are

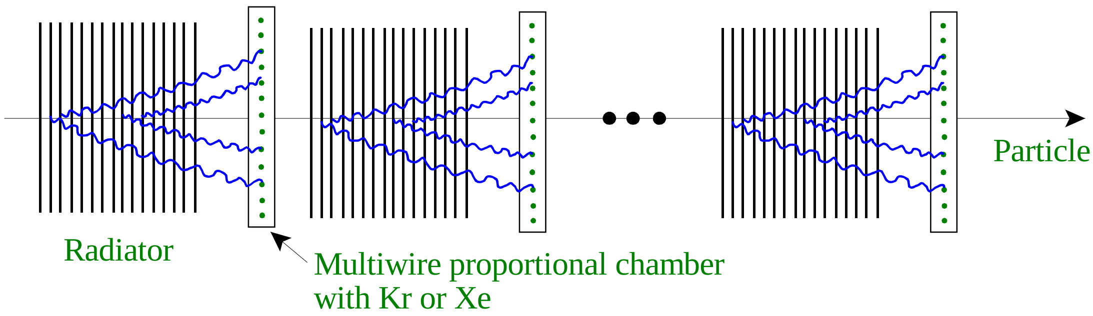
$$\langle N_{ph}\rangle \sim \frac{1}{2}\alpha \qquad \theta \sim 1/\gamma$$

TRD

Practicle detectors are made up of stacks of thin foils or fibers, thereby providing many interfaces.

With more than one surface, interference effects can arise from the superposition of the radiation.

Foils must have a minimium thickness, called the *formation zone*, so the electromagnetic field can fully develop.



Radiator

The radiators must have small X-ray absorption so that the photons can reach the chamber.

- Low Z since $\sigma_{Photo} \propto Z^4$
- Long radiation length
- Long interaction length

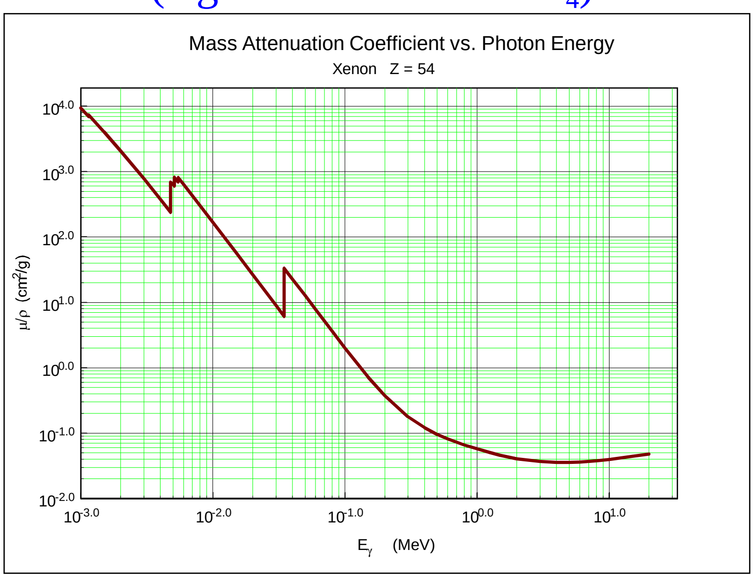
The best radiation material is lithium, but it is difficult to handle.

Other radiator materials used are:

Carbon fibers
polyethylene
polypropylene
polyurethane
polystyrene

Detector

The standard method for detecting the TR photons is a multiwire proportional chamber filled with xenon (e.g. 90% Xe/ 10% CH_4).

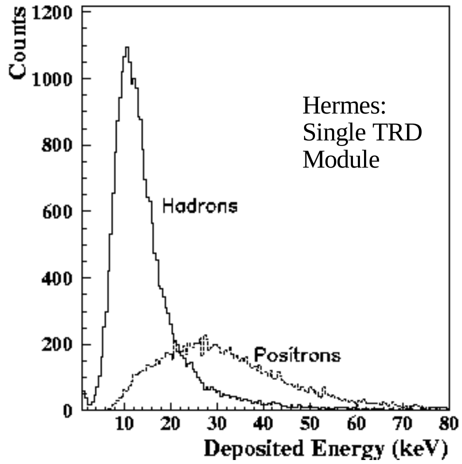


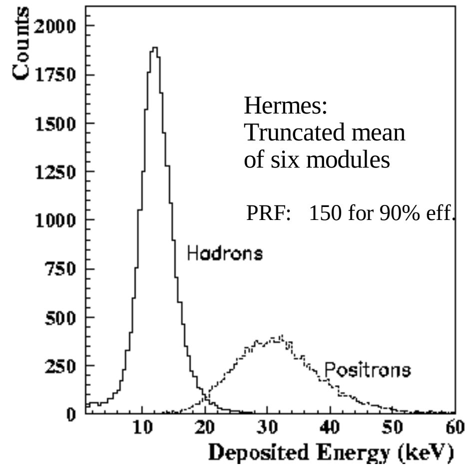
Particle ID Methods:
Total Charge

Conventional method is to sum the total ionization and TR X-rays.

Need large # of X-ray photons from TR

Problem: big ionization fluctuations (δ-rays)

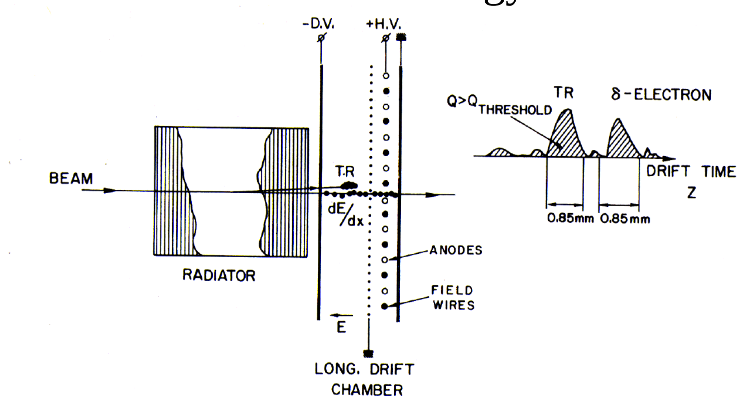




Particle ID Methods:
Cluster Counting

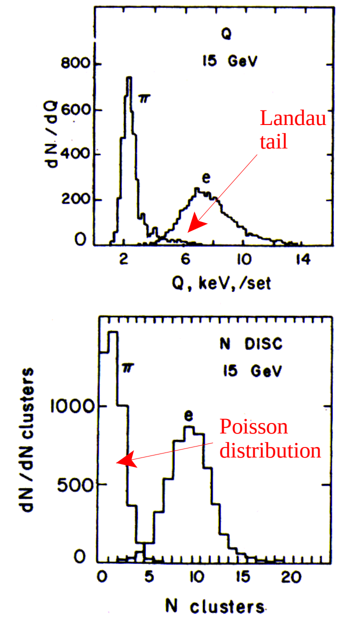
Alternative method: study the charge distribution along track.

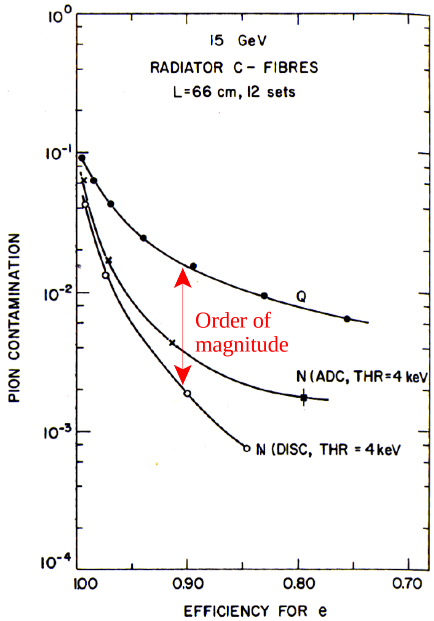
Advantage: distribution of the number of ionization clusters is better behaved than the total ionization energy.



Cluster Counting

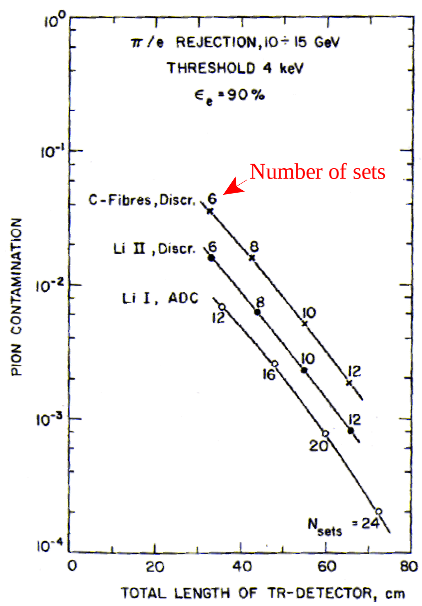
C.W. Fabjan, *et al.*, Nucl.Instrum.Meth.185:119-124,1981.





Cluster Counting
π/e vs. Length

Fabjan, *et al.*



Li I: 30 μm thickness; 160 ± 80 μm foil separation; one radiator: 0.19 g/cm^2

Li II: 35 μm thickness; 240 ± 80 μm foil separation; one radiator: 0.30 g/cm^2

C-fibers: 7 μm thickness; one radiator : 0.30 g/cm^2

Conclusion

- TRD detector technology is well established
- Pion rejection factors > 100 are feasible.
- No problem putting TRD in front of Shower counter since Radiation length ~ 5 -10%
- At higher energies, more practical than threshold Čerenkov detectors, since $L_{\check{C}} \propto P^2$