Ionization loss

Jonathan F. Ormes

Space Sciences Director, GSFC, Emeritus

University of Denver

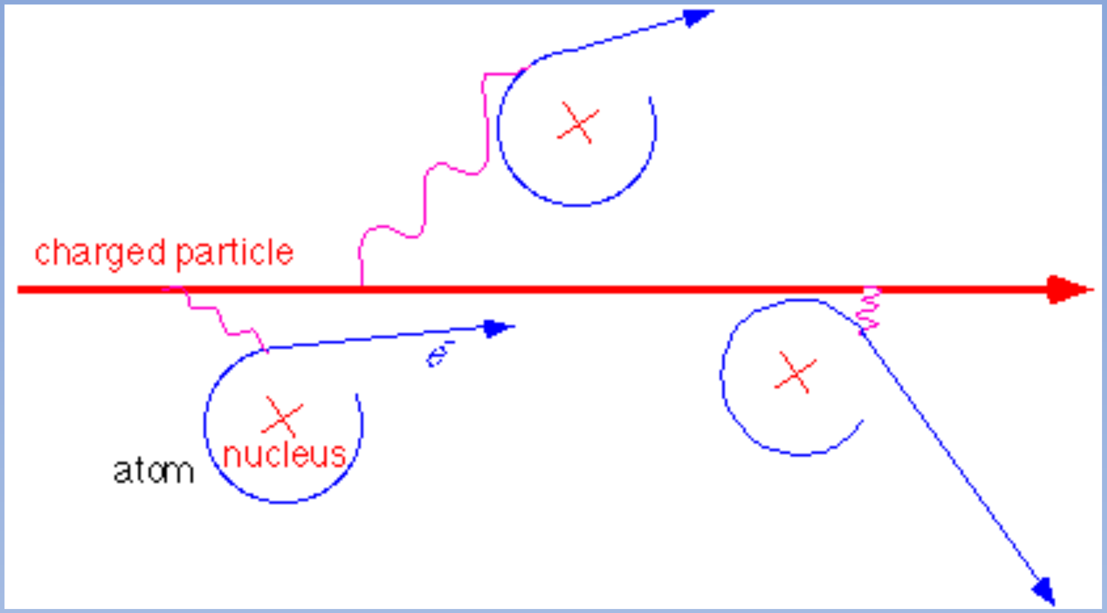
Winter, 2019

Wind Crest Learners

Academy for Lifelong Learning

Ionization energy loss in matter

Energetic incoming particle with energy E.



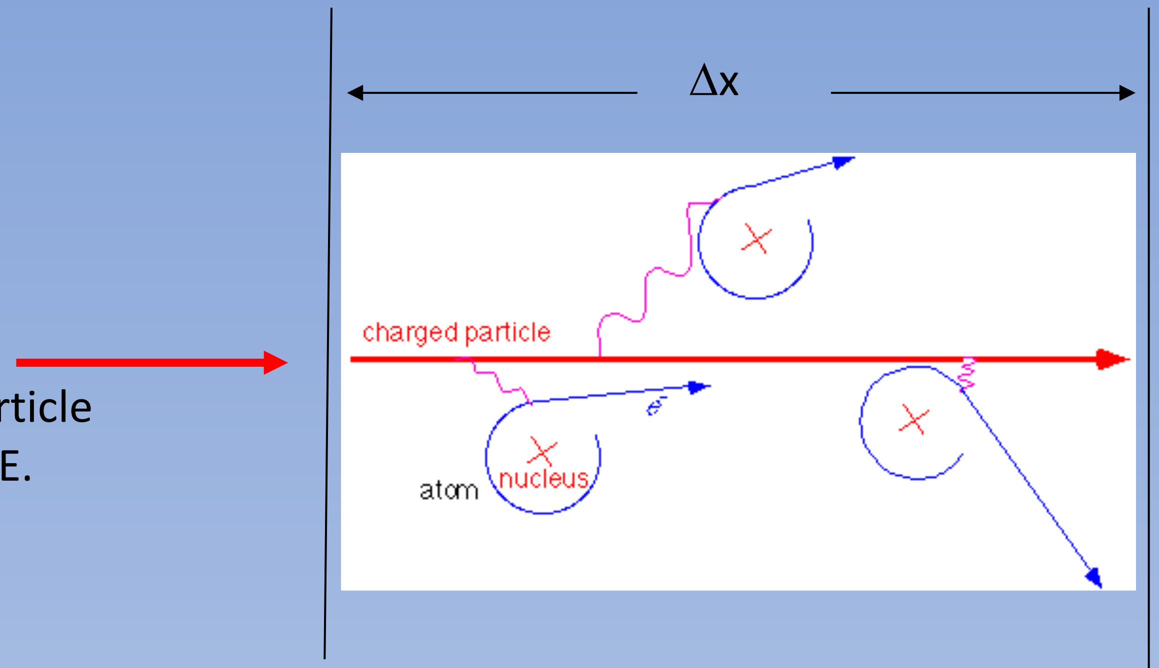
Outgoing particle with energy E-ΔE.

Xs represent atomic nuclei and the blue represent orbital electrons.
After the passage of the energetic particle, the medium is ionized and the incoming particle has a little less energy.

It leaves the material "ionized". In some cases this doesn't last too long because the electrons find an ion with which to recombine.

Ionization energy loss ΔE is proportional to Δx

Energetic incoming particle with energy E.

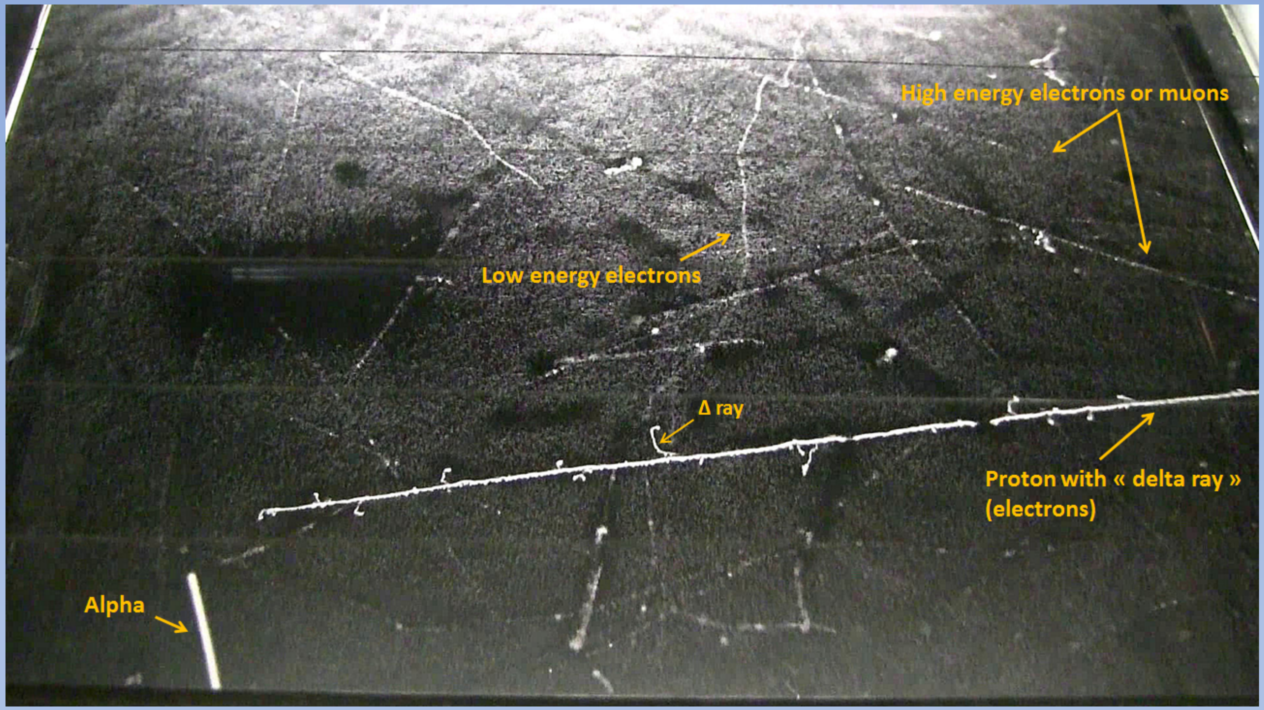


Outgoing particle with energy E-ΔE.

In detectors, the ions are counted somehow. The ions usually don't last long because the electrons find an ion with which to recombine. The bonding process liberates photons (light) that can be detected. By detecting the light of recombination, we can infer the energy loss, ΔE, of the incident particle.

Delta rays

All along the track of the particle there are lots and lots of electrons emitted. These are known as delta rays. They are what makes the black track in emulsions.

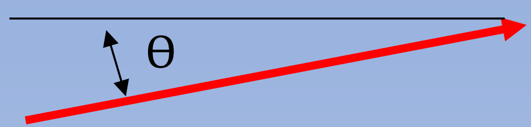


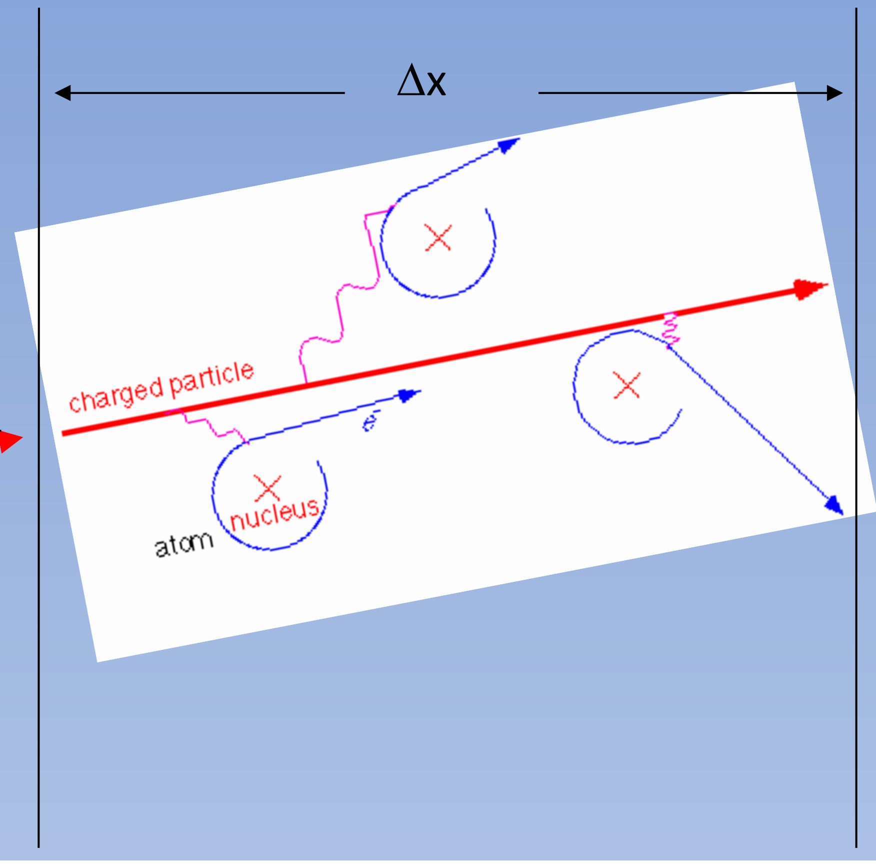
White tracks here in this negative image!

In air they travel further (less dense material) and contribute to the background radiation. These e^- can also ionize along their tracks.

Ionization energy loss ΔE is proportional to Δx

Energetic incoming particle with energy E.





Particle Deposits energy ΔxΔE/cos(θ) in the slab.

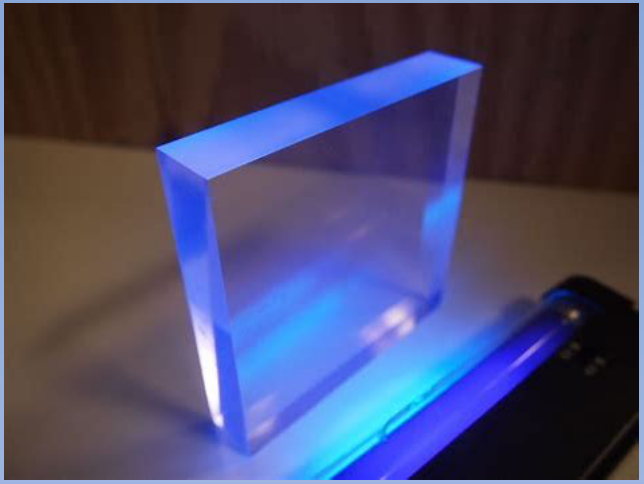
Our detectors were slabs of plastic, Δx about 1 cm thick, doped with what were called scintillating chemicals that grabbed the energies of recombination and turned it into visible light.

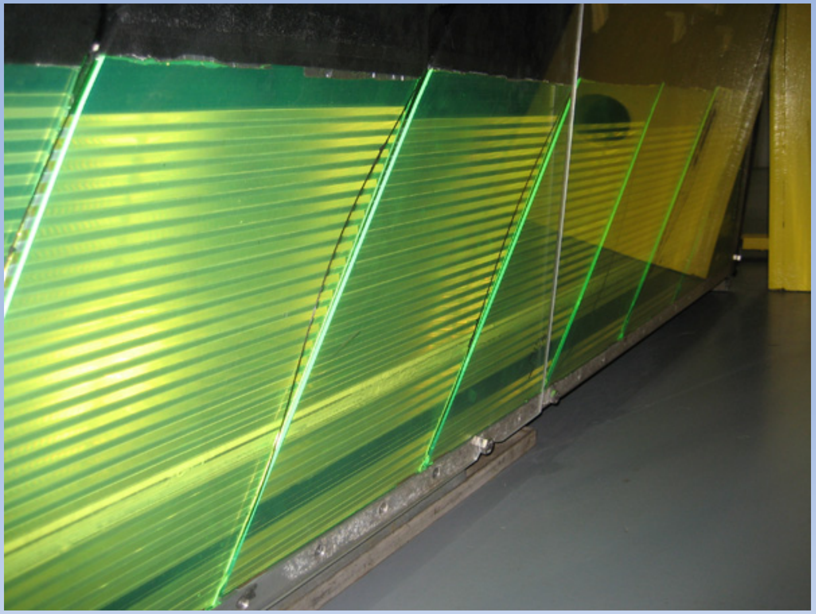
We call this process "waveshifting".

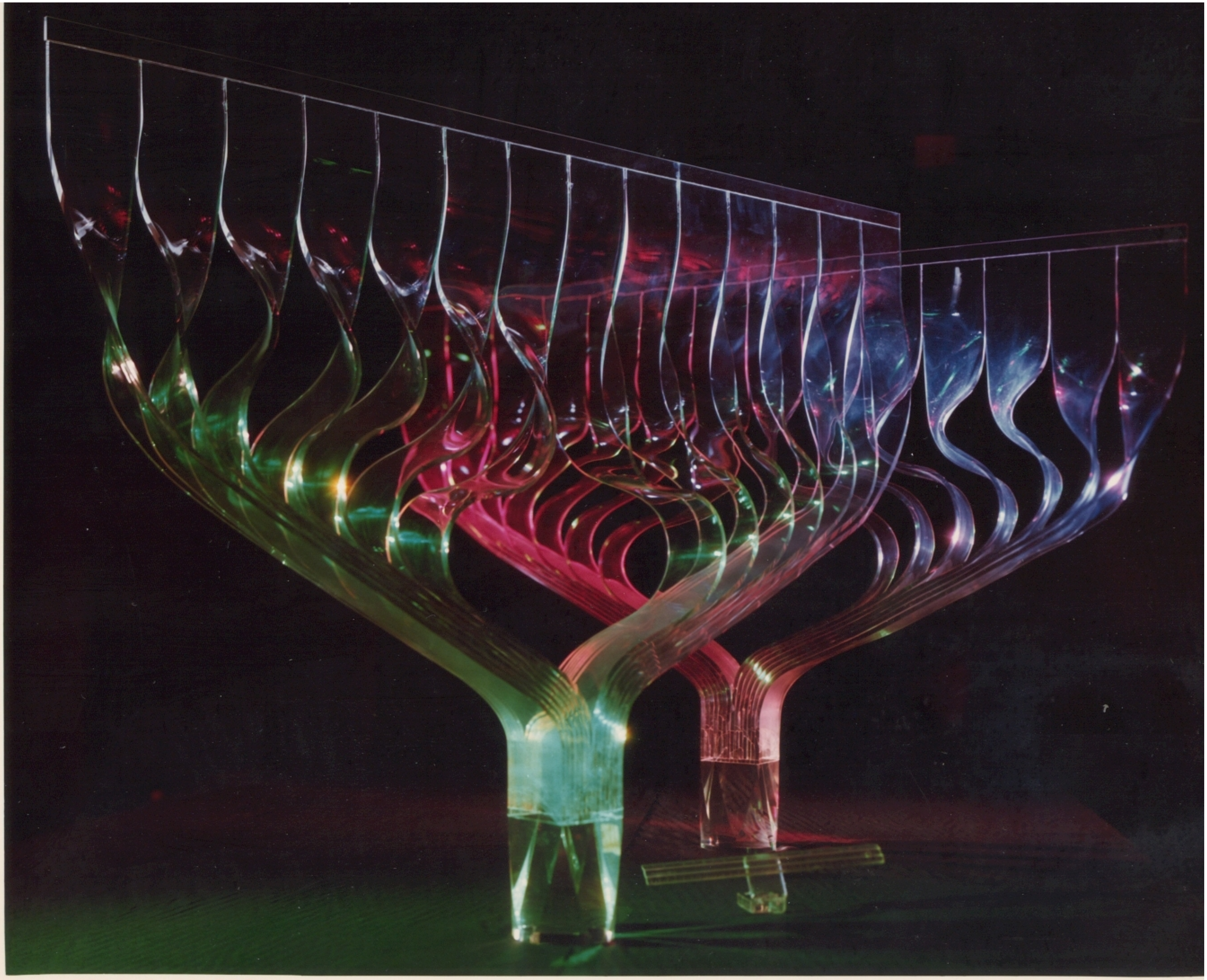
Bluing chemical for laundry soap

All it is – a chemical waveshifter to the blue because people thing bluer is cleaner.

Scintillators

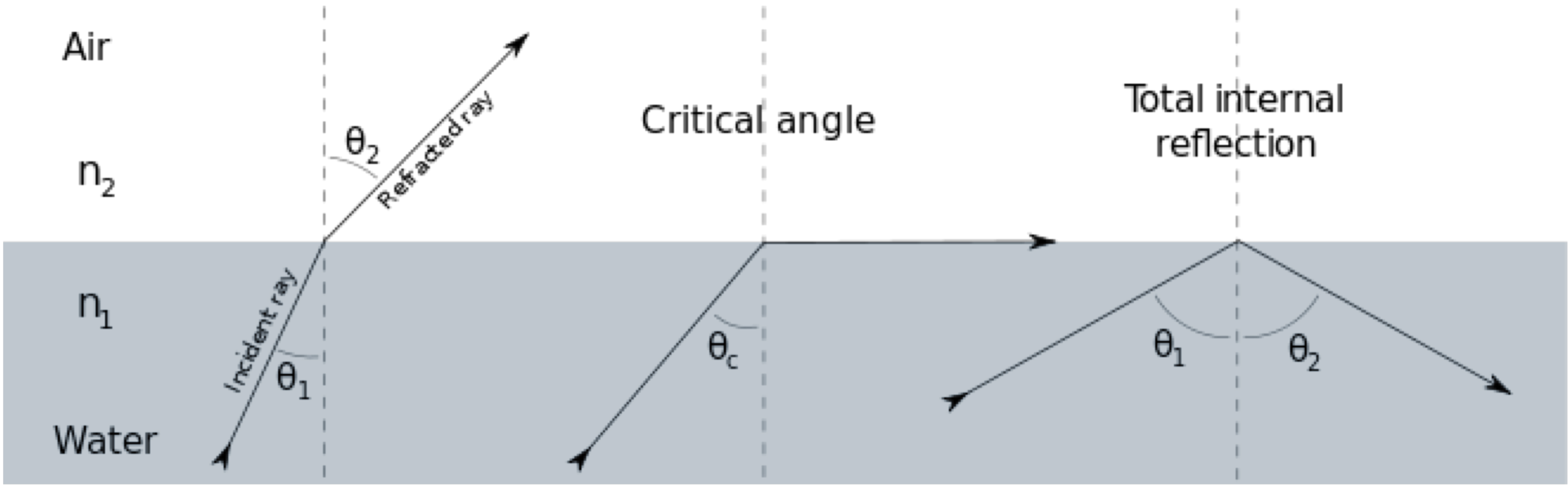




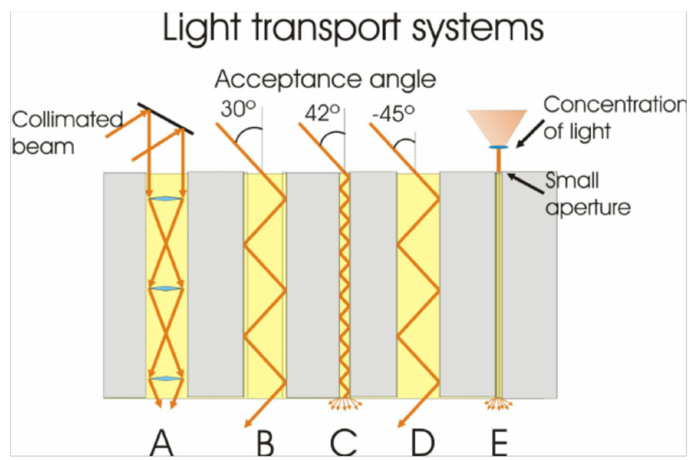


NASA G-76-02501

Light propagates by total internal reflection



Fiber optics, guided light,
Essentially lossless reflection.



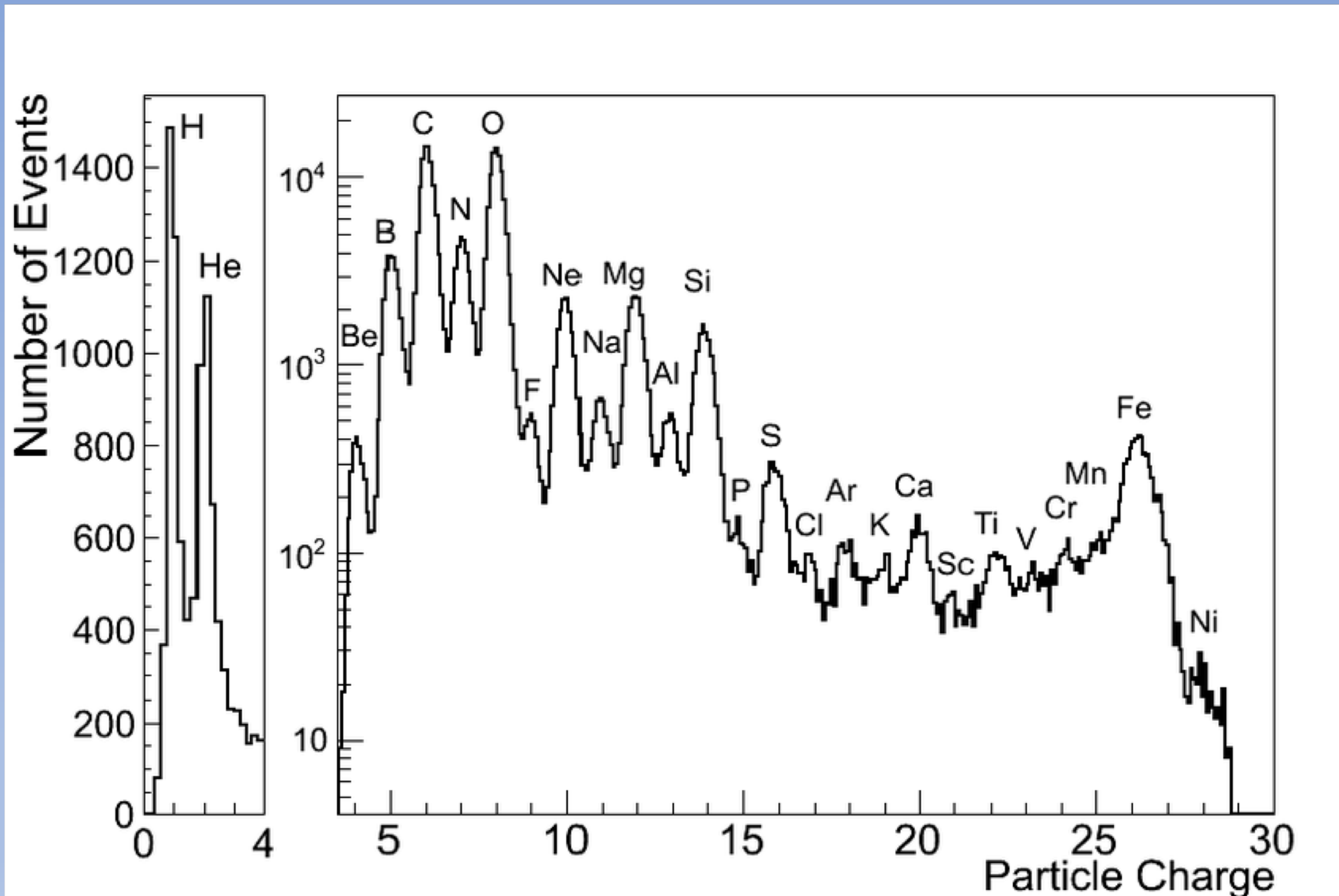
Light produced goes as the square of the particle's charge, Z^2

Energy loss/(length of material traversed) is proportional to the square of the charge.

$$\frac{\Delta E}{\Delta x} \propto Z^2$$

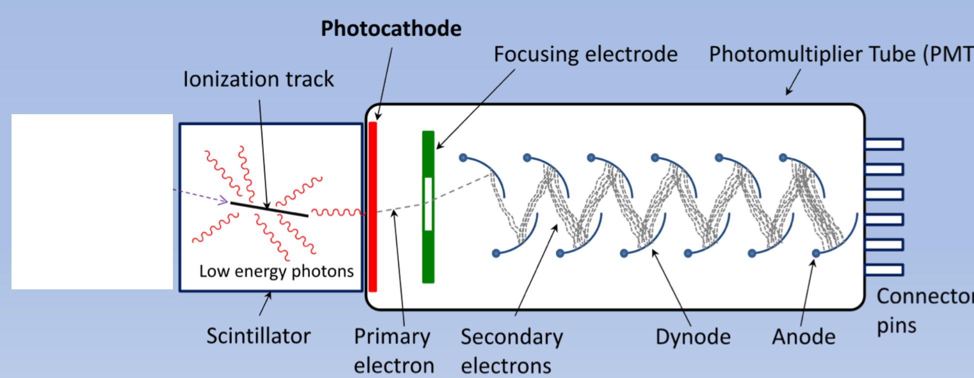
This is one of the ways we "see" the charge of the particle.

Charge distribution measured



To see the blue light we used something called a <u>photomultiplier</u>.

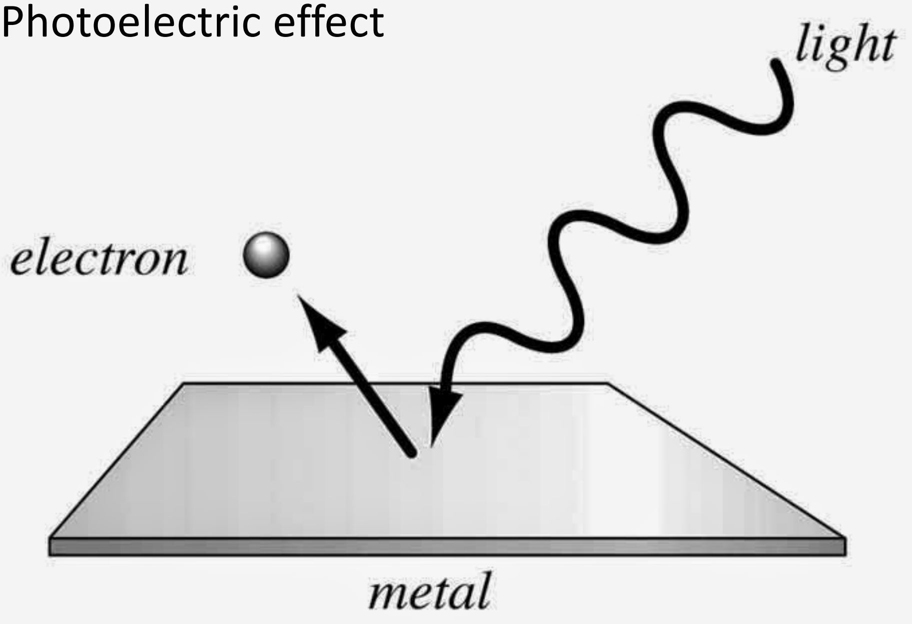
It turns a quantity of light into a proportional electrical signal.



Photoelectric effect – Einstein Nobel Prize 1921

Photons are absorbed in the metal and electrons are emitted.
It is called the photo-electric effect.
It was first described by Einstein.

Photoelectric effect

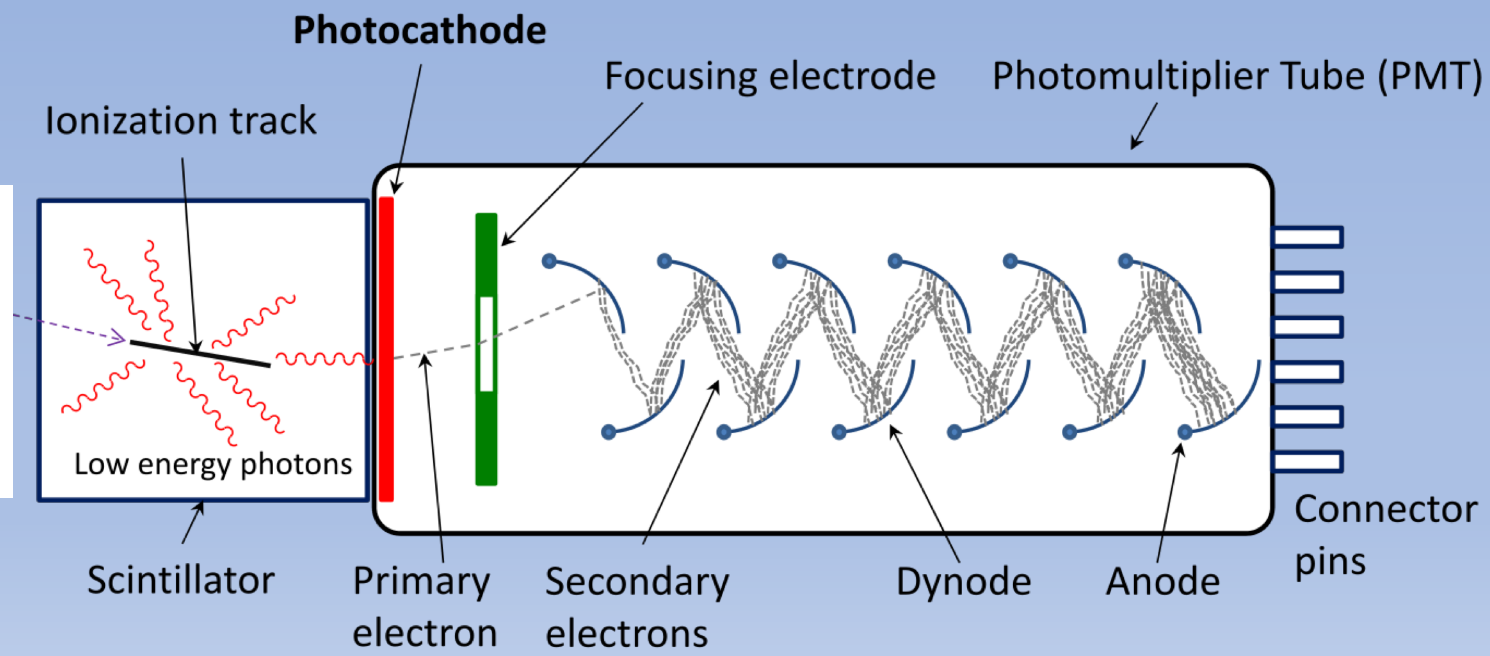


If the layer of metal is thin, the electron can leave through either surface.

Light can be converted to an electrical signal. Energy proportionality is maintained.

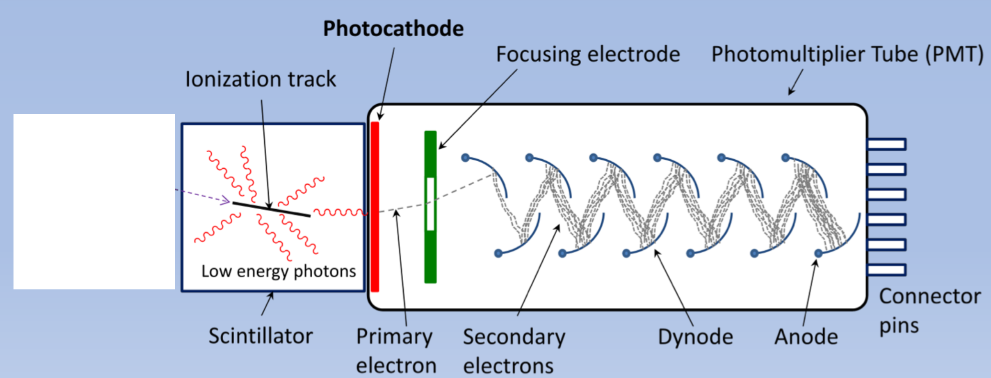
Signal is multiplied electronically

The surfaces of these tubes are covered with a material called aa photocathode that is sensitive to blue light. The blue photons are absorbed in the photocathode and electrons are emitted. The signal is then amplified into a useful electrical signal as the electrons are accelerated to the different cathodes.



Seeing charged particles

Count the ions produced in a slab of plastic called a scintillator
that is doped with a chemical that produces a light signal when the ions recombine with electrons.



Detection chain

- $\Delta E/\Delta x$ energy loss in a slab of material
- Electrons in the slab recombine with the ions to produce light
- Light is chemically “waveshifted” to be blue light
- Blue light is captured by total internal reflection in plastic “light guides” and sent to the photocathodes of photomultipliers
- Photocathodes absorb the blue light and emit an electron.
- Electron signal is multiplied into a bigger usable electrical signal by the photomultipliers.