GAMMA SCANNING

U-235 is the material in LWR nuclear fuel that fissions and produce energy.

Gamma scanners measure the amount of U-235 in each fuel pellet of the fuel rod.

Natural uranium is only 0.7% U-235, remainder is U-238. It is enriched to 2-5% U-235 for use in PWR reactors.

U-238 decays producing daughters which emit gamma rays, interfering with natural gamma rays from U-235

The fuel rod moves past the detectors in the scanner at fixed speed. Counts of gamma rays are taken from pellets at fixed intervals along the length of the fuel rod, from each detector.

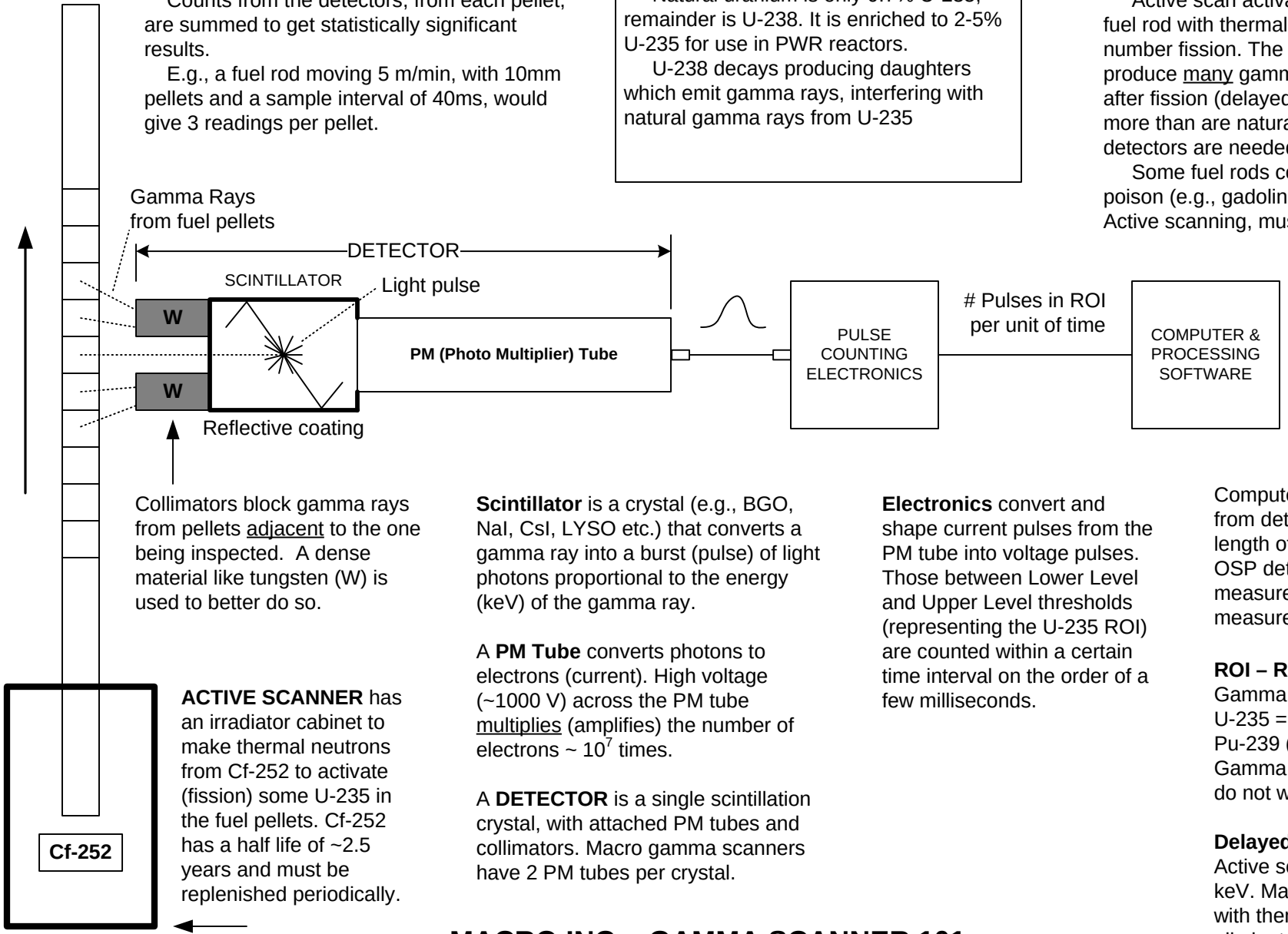
Counts from the detectors, from each pellet, are summed to get statistically significant results.

E.g., a fuel rod moving 5 m/min, with 10mm pellets and a sample interval of 40ms, would give 3 readings per pellet.

Passive Scanner reads natural U-235 gamma rays. There are not very many of them. Have to take many measurements along the length of the fuel rod to get good values (statistically).

Active scan activates the U-235 in the fuel rod with thermal neutrons so a small number fission. The fission products produce <u>many</u> gamma rays for a time after fission (delayed gammas) many more than are naturally emitted so fewer detectors are needed.

Some fuel rods contain a neutron poison (e.g., gadolinium) that prevents Active scanning, must be passive.



Collimators block gamma rays from pellets <u>adjacent</u> to the one being inspected. A dense material like tungsten (W) is used to better do so.

ACTIVE SCANNER has an irradiator cabinet to make thermal neutrons from Cf-252 to activate (fission) some U-235 in the fuel pellets. Cf-252 has a half life of ~2.5 years and must be replenished periodically.

Scintillator is a crystal (e.g., BGO, NaI, CsI, LYSO etc.) that converts a gamma ray into a burst (pulse) of light photons proportional to the energy (keV) of the gamma ray.

A **PM Tube** converts photons to electrons (current). High voltage (~1000 V) across the PM tube <u>multiplies</u> (amplifies) the number of electrons ~ 10^7 times.

A **DETECTOR** is a single scintillation crystal, with attached PM tubes and collimators. Macro gamma scanners have 2 PM tubes per crystal.

Electronics convert and shape current pulses from the PM tube into voltage pulses. Those between Lower Level and Upper Level thresholds (representing the U-235 ROI) are counted within a certain time interval on the order of a few milliseconds.

Computer adds up readings from detectors along full length of fuel rod to perform OSP detection, length measurements, enrichment measurements etc.

ROI – Region of Interest
Gamma Ray Energy
U-235 = 186 keV
Pu-239 (MOX) =~ 450 keV
Gamma Rays outside ROI we do not want.

Delayed gamma rays in Active scanners average 1000 keV. Macro electronics deals with them differently to eliminate counting losses.

MACRO INC. - GAMMA SCANNER 101