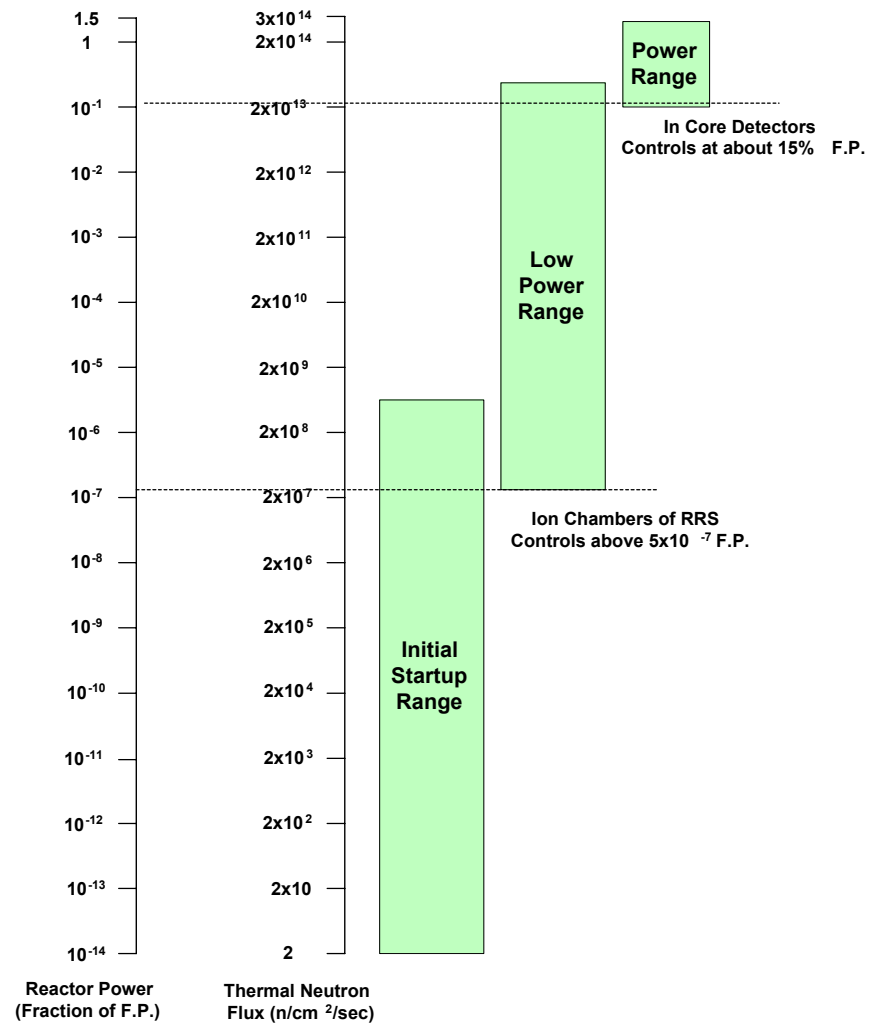
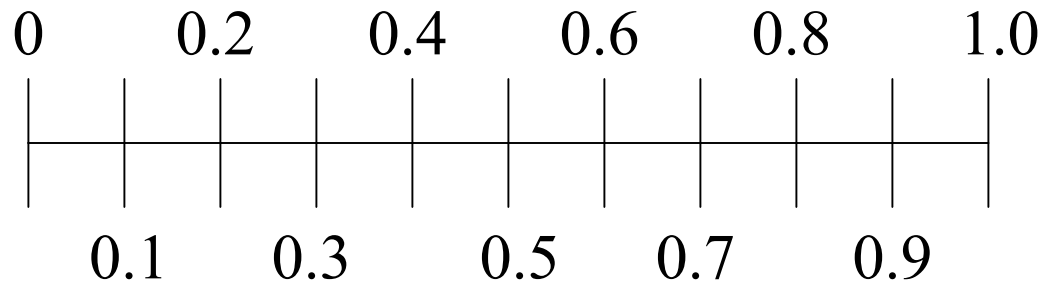


Neutron Flux Measurement

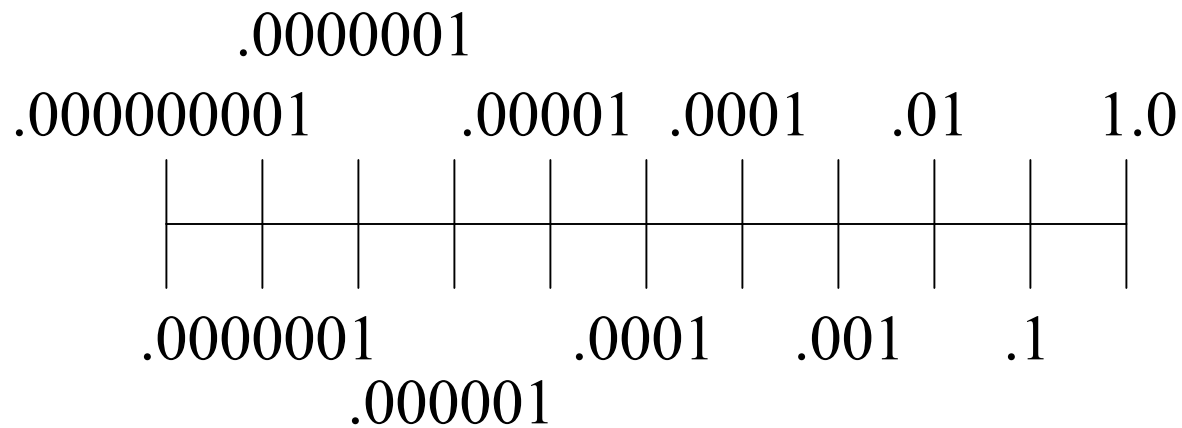




Log vs. Linear Meters

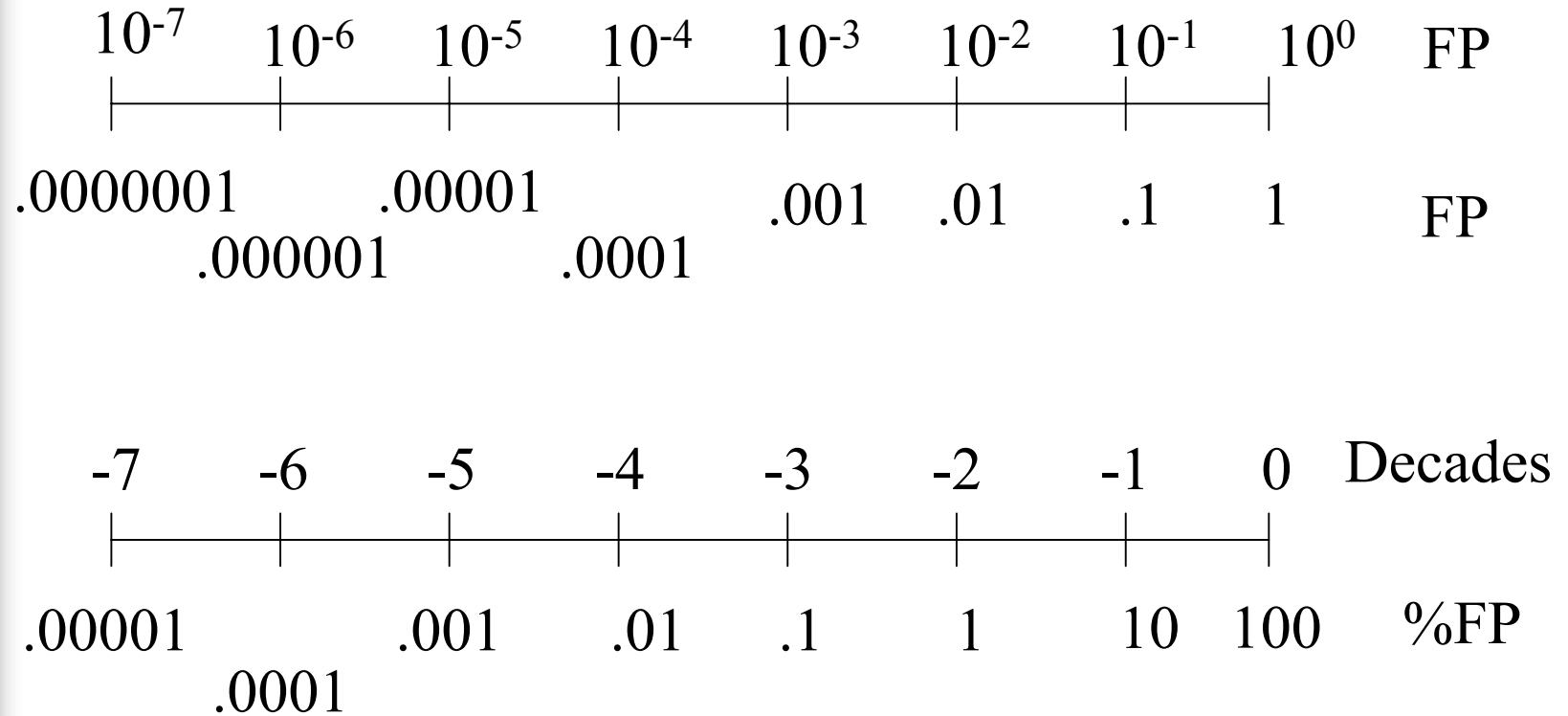


Linear
Scale



Log
Scale

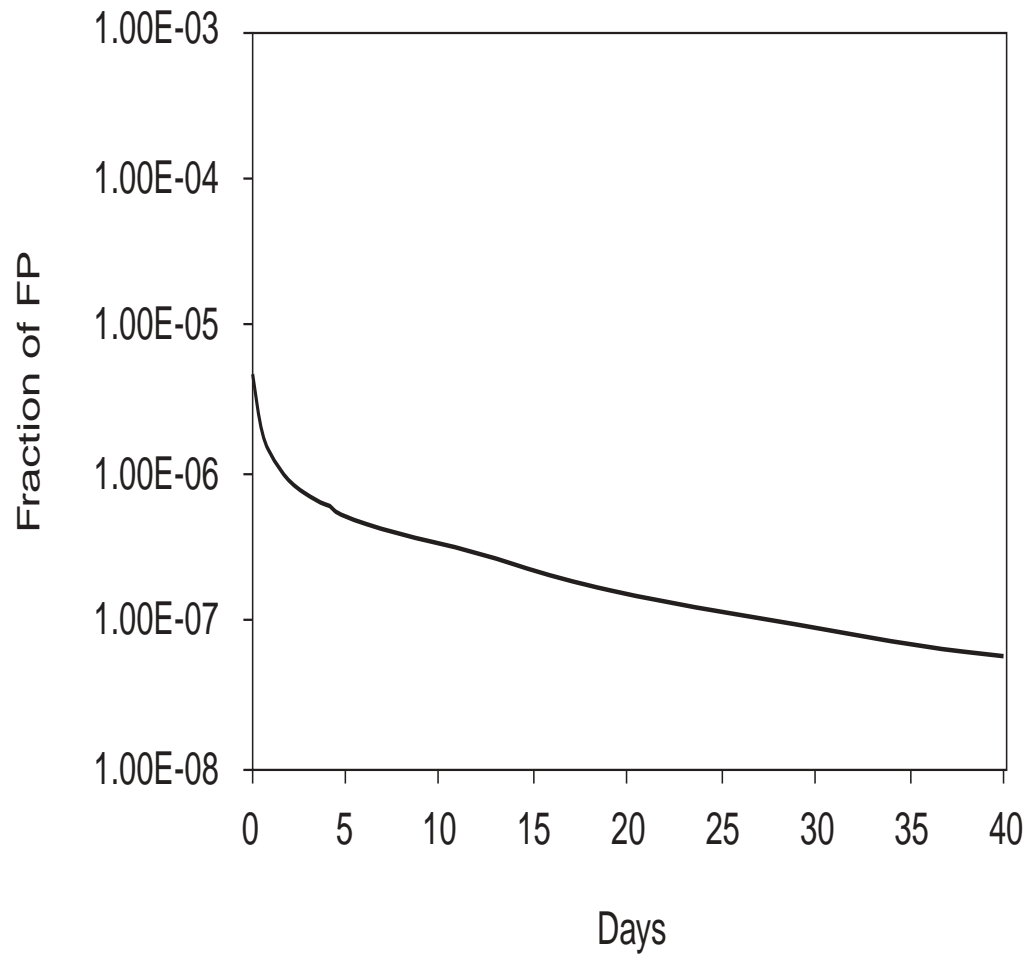
Four Power Scales



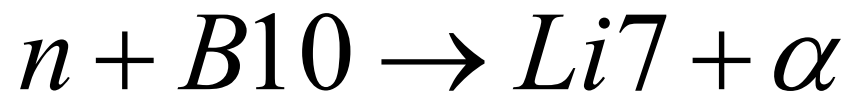
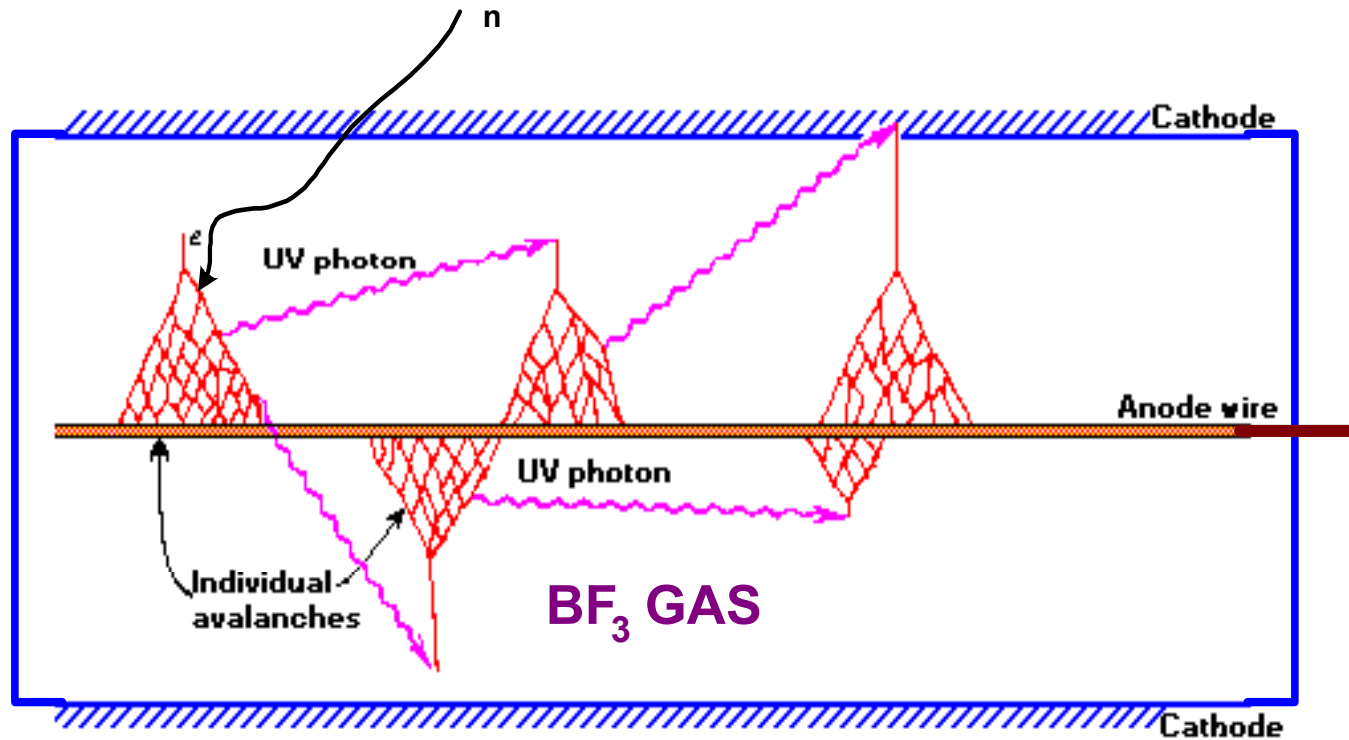
Startup Instrumentation



Reactor Power After Shutdown



Boron Tri-fluoride Detectors





More about Start-up Instrumentation

- He-3 detectors can also be used
 - More sensitive to neutrons
 - Smaller current pulse
- Detector come in a number of sizes
- Normally detectors are external to the core
- Installed only when needed



Even More About Start-up Instrumentation

- Typically installed in spare ion chamber holes
- Provisions for installing right into the core
 - New cores
 - Extremely long shutdowns
- Detector Burnout
- Damped response



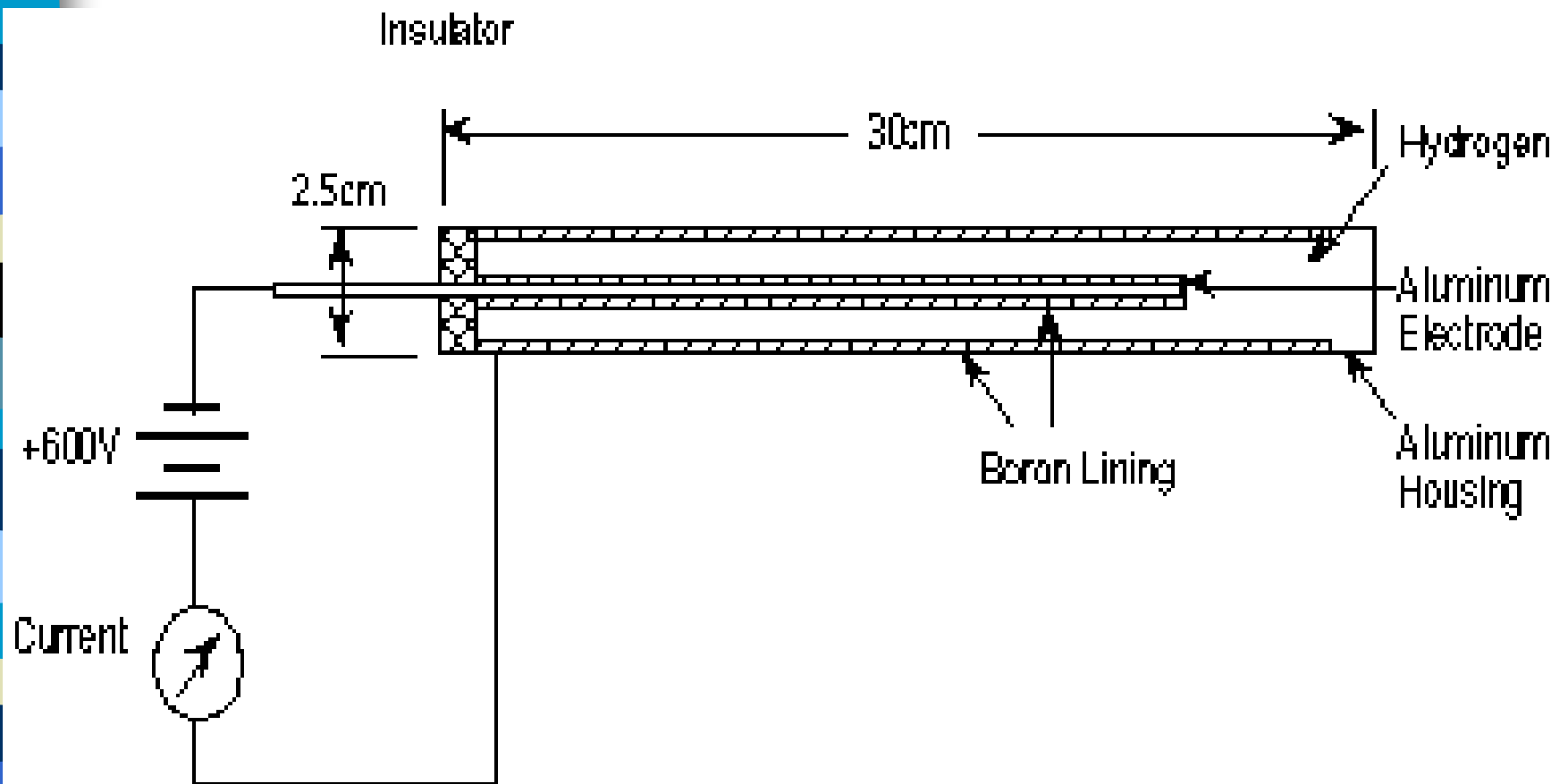
Fission Chambers

- Enriched Uranium lines the walls of a chamber
- Inert fill gas
- Neutrons cause fissions in the U235
- Ionizations from the fission products are detected
- Can incorporate U-238 to breed more active

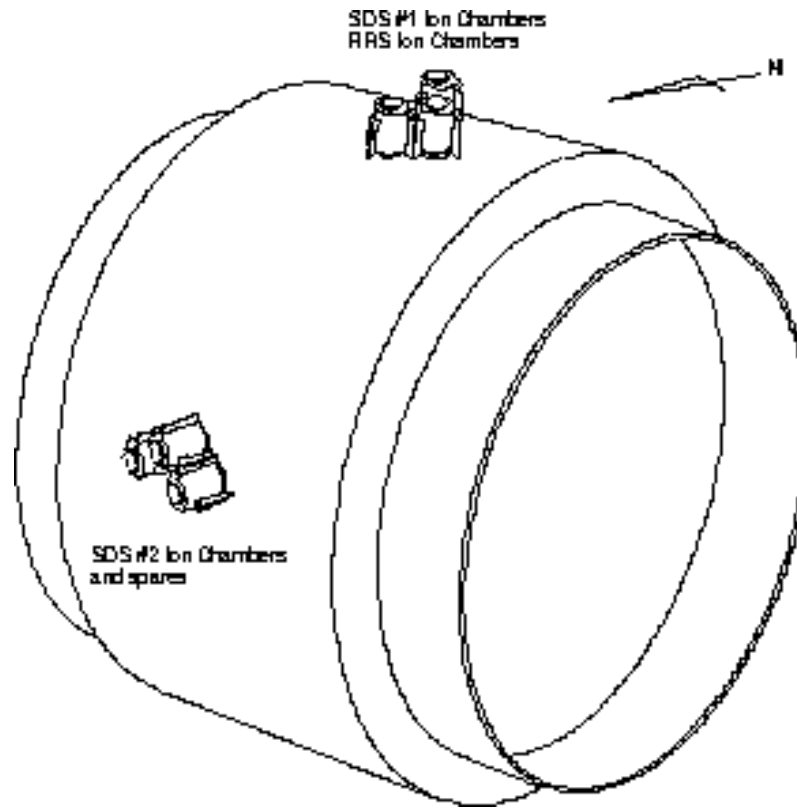
Run up Instrumentation



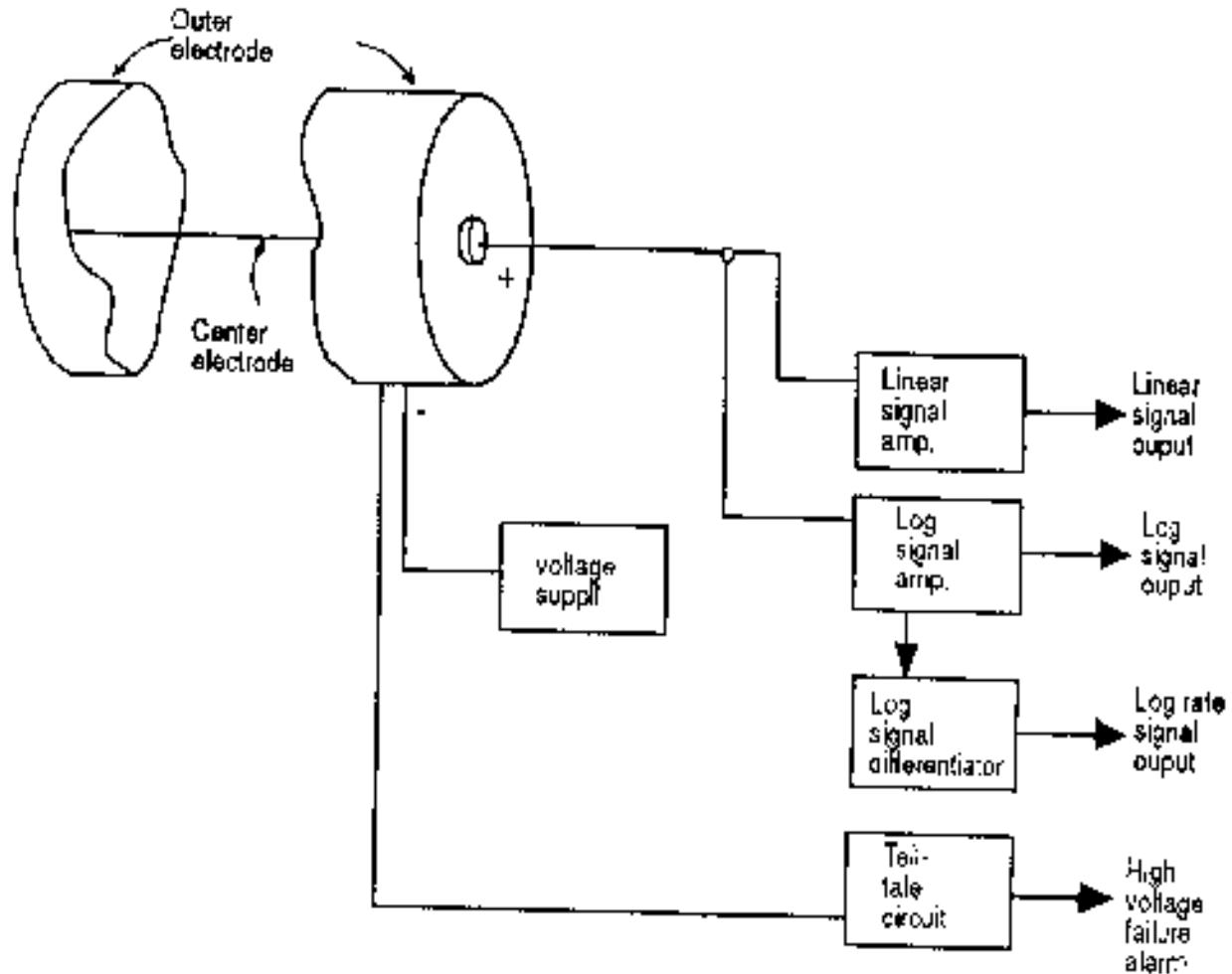
Ion Chambers



Typical Ion Chamber Locations



Ion Chamber Circuits





Gamma Discrimination

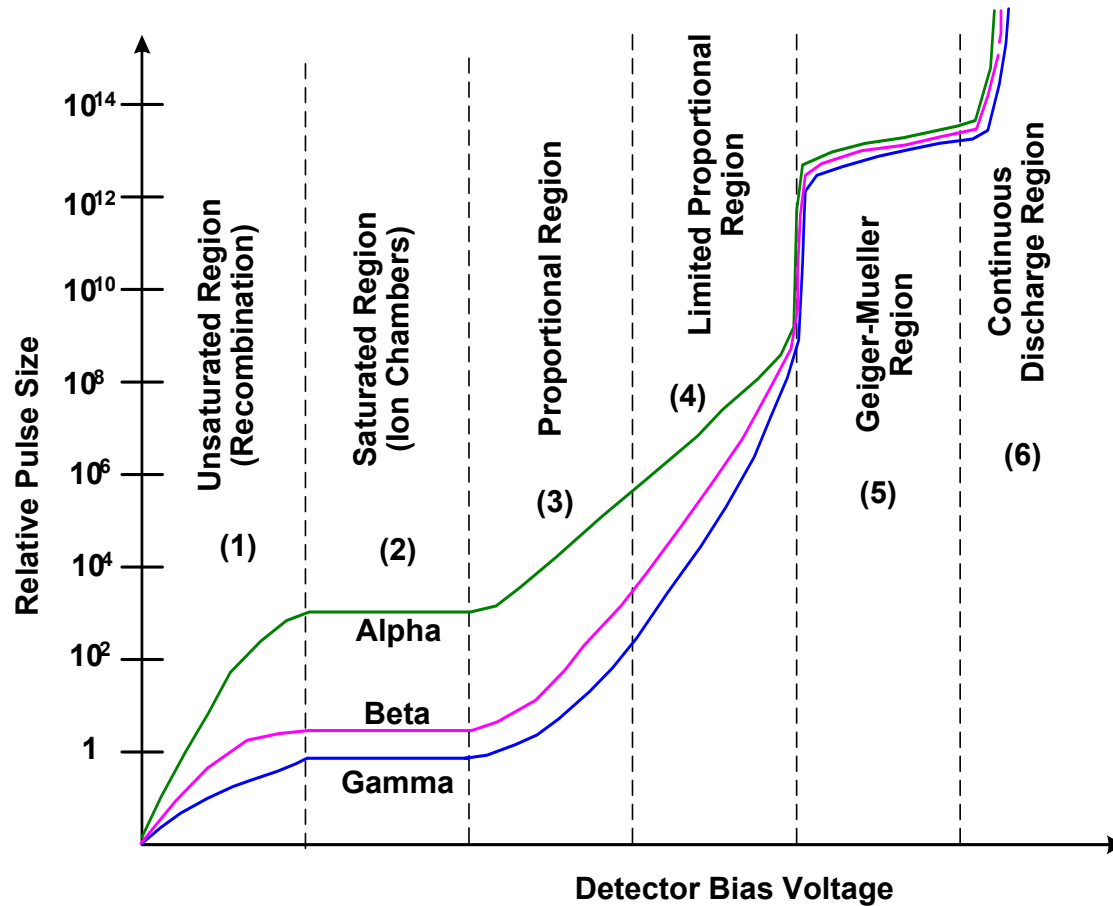
- Minimizing the effect of gamma
- Small detectors
 - Minimize gamma energy deposited
- Lead Shielding
 - Lead absorbs gamma but is relatively transparent to neutrons



Ion Chamber Accuracy.

- Moderator Level
 - Changes in moderator level affect the spectrum
- Loss of high voltage
- Low reactor power levels
- High Voltage Drift

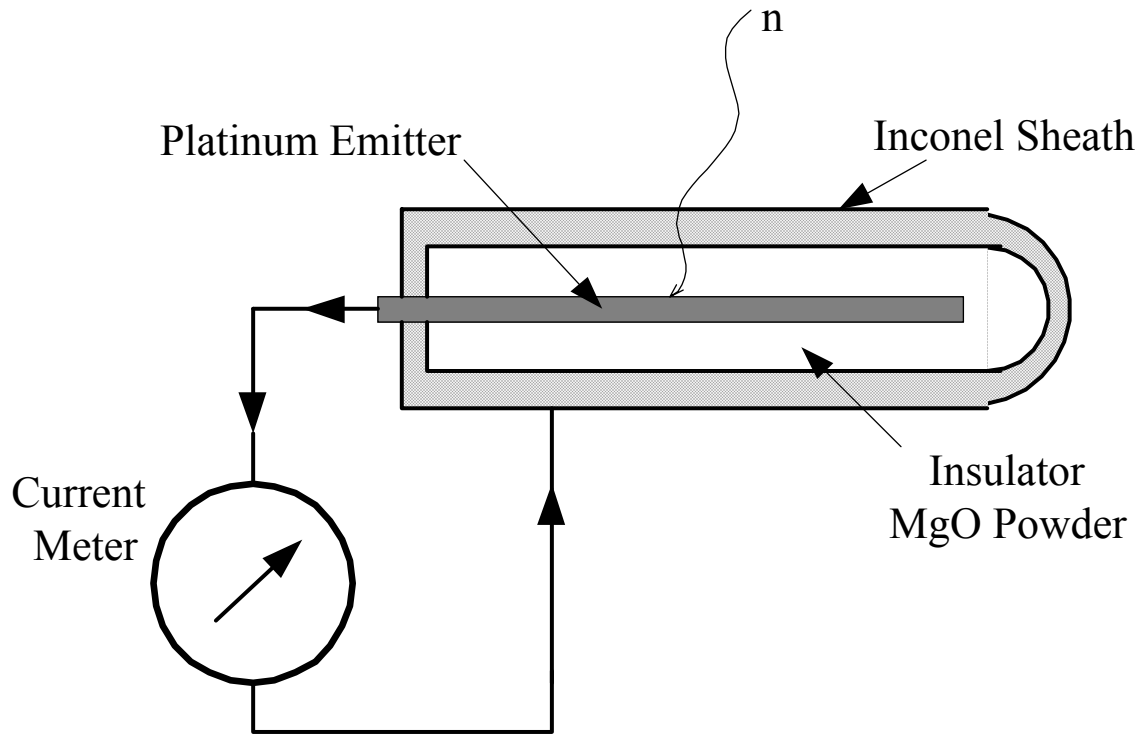
Gas Detector Curves



Under Load Instrumentation



In-Core Detectors

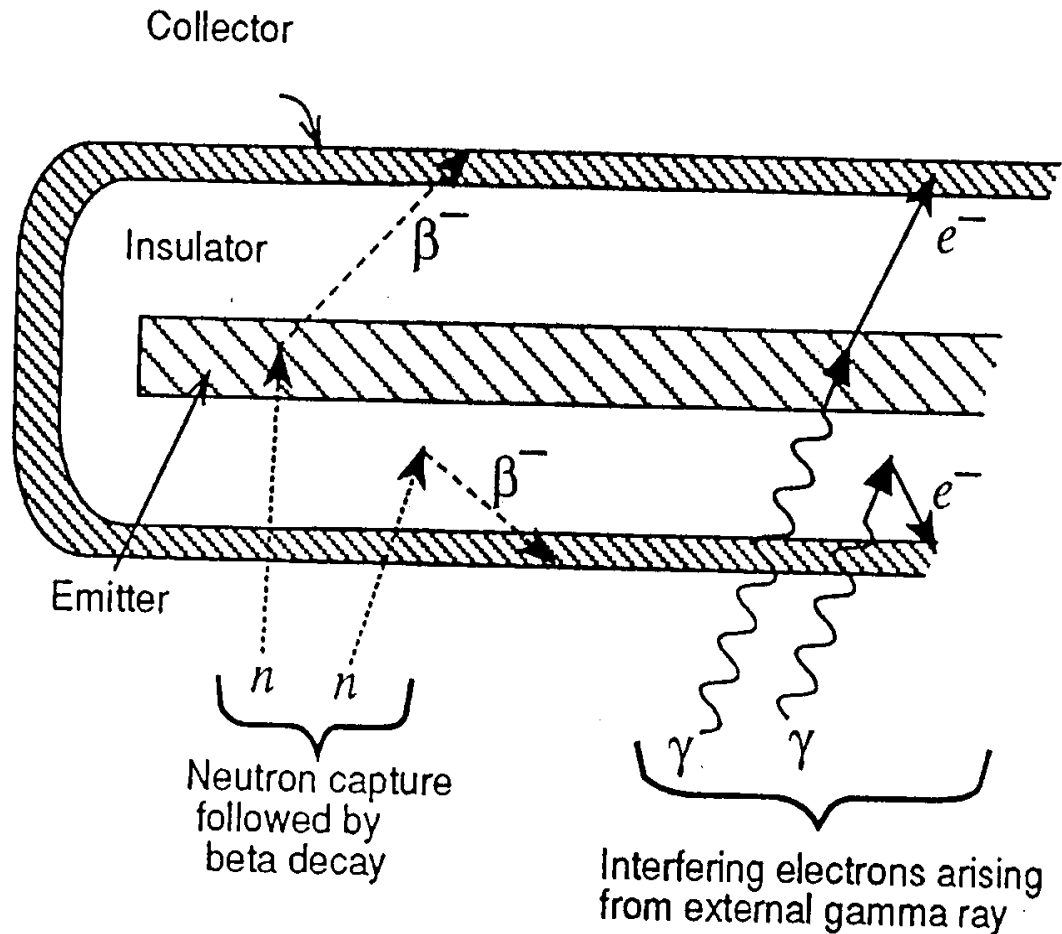




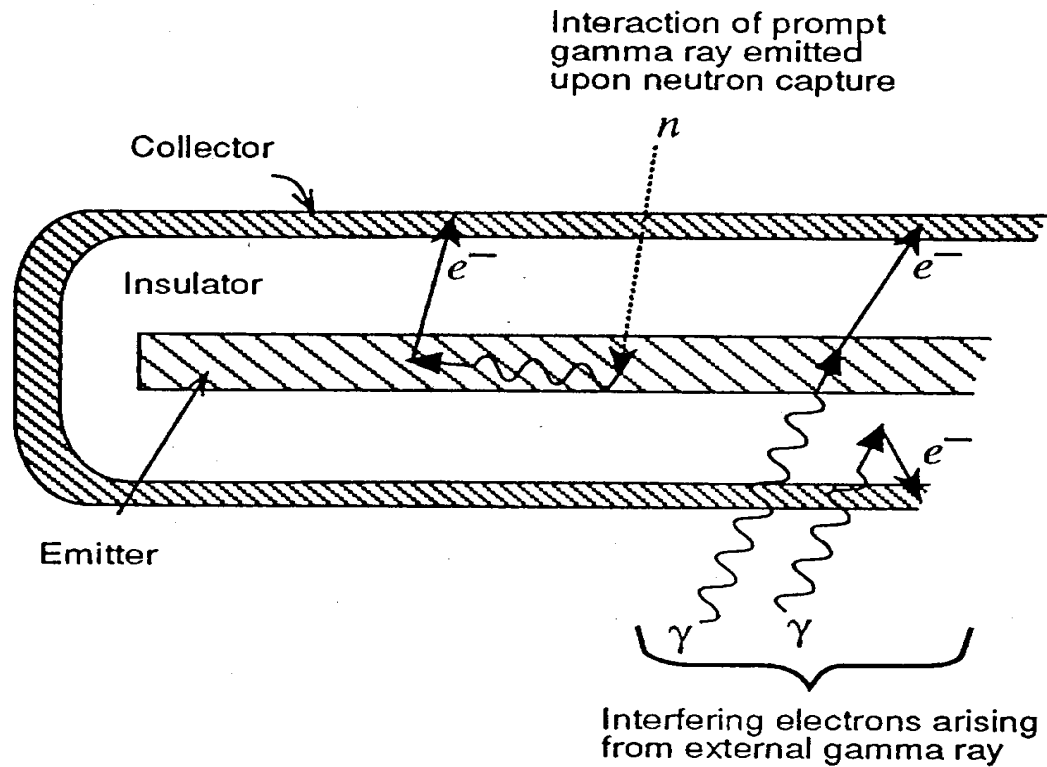
Major Reactions

- Neutron capture and later beta decay
- Neutron capture followed by a gamma and the gamma releases a Compton or photo electron
- Gamma from external source releases an a Compton or photo electron

Neutron Beta reaction



Neutron Gamma Reaction





Response of Detectors

- (n, B) response is delayed after a change in neutron population
- (n, γ) response is prompt following a change in neutron population
- External γ is prompt for fission gammas
- External γ is delayed for fission products



Platinum Detectors

- Beta gives 3% of signal
- Neutron capture gammas 60%
- External gammas 40%



Inconel Detectors

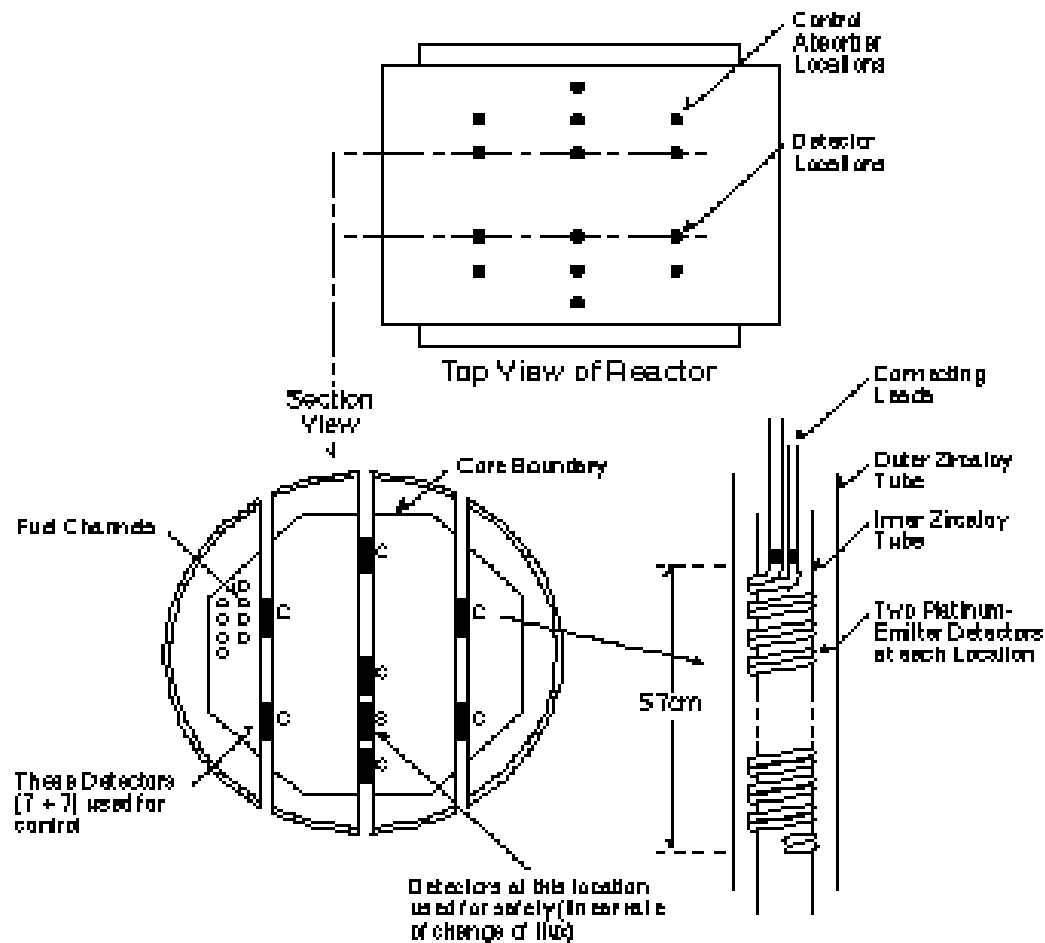
- Negligible (n, B)
- Almost all signal from (n, γ) followed by photo or Compton electron
- Over prompt response



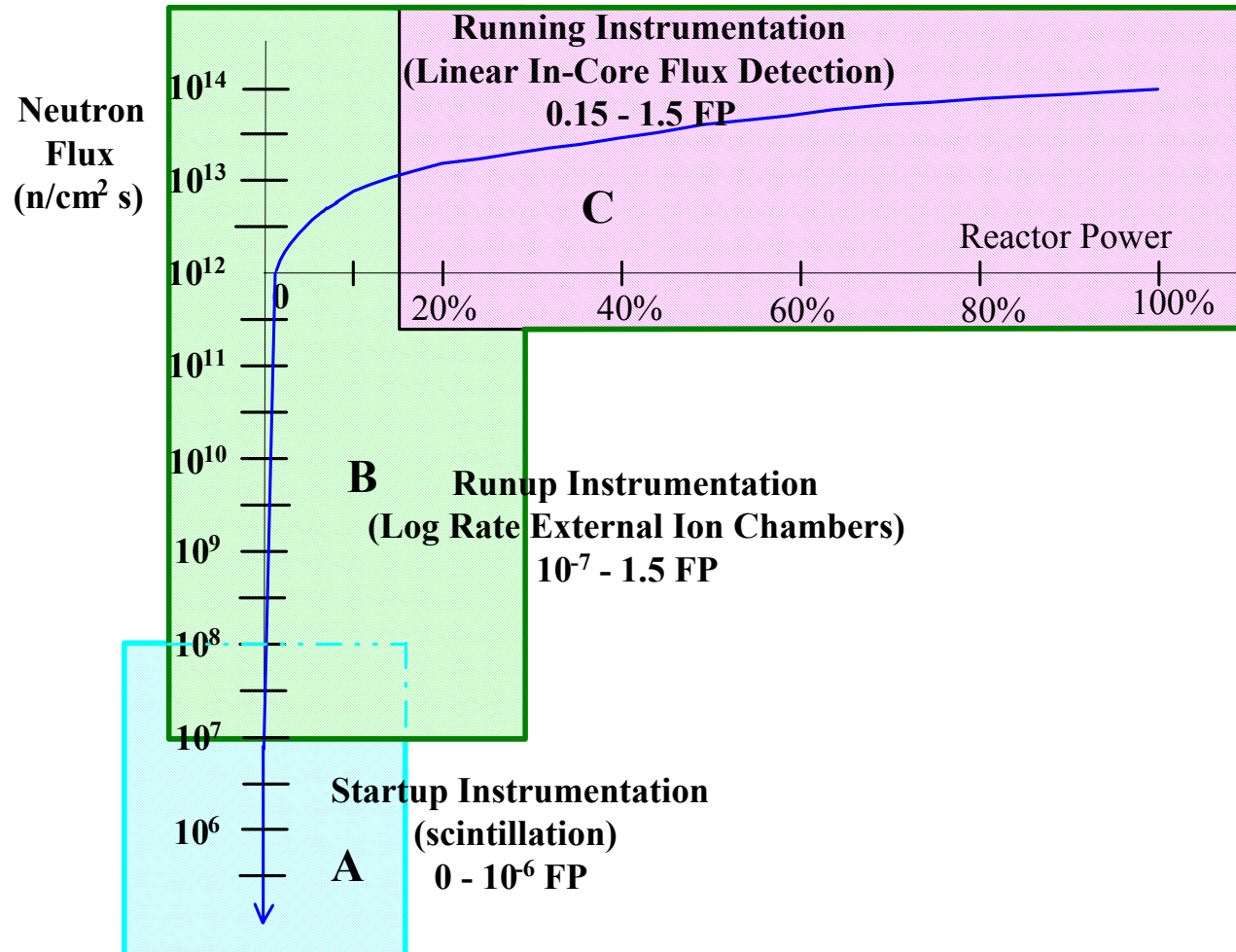
Vanadium

- Almost all response is (n,B)
- Response is delayed

Detector Location



Overlapping Ranges





In-Core Detector Accuracy

- Fuelling or reactivity device movement
- Start-up of the reactor
- Long term exposure
- Moderator poison load



For You To Do

- Read pp. 60-80
- Answer Questions pp. 86-88, #28-38