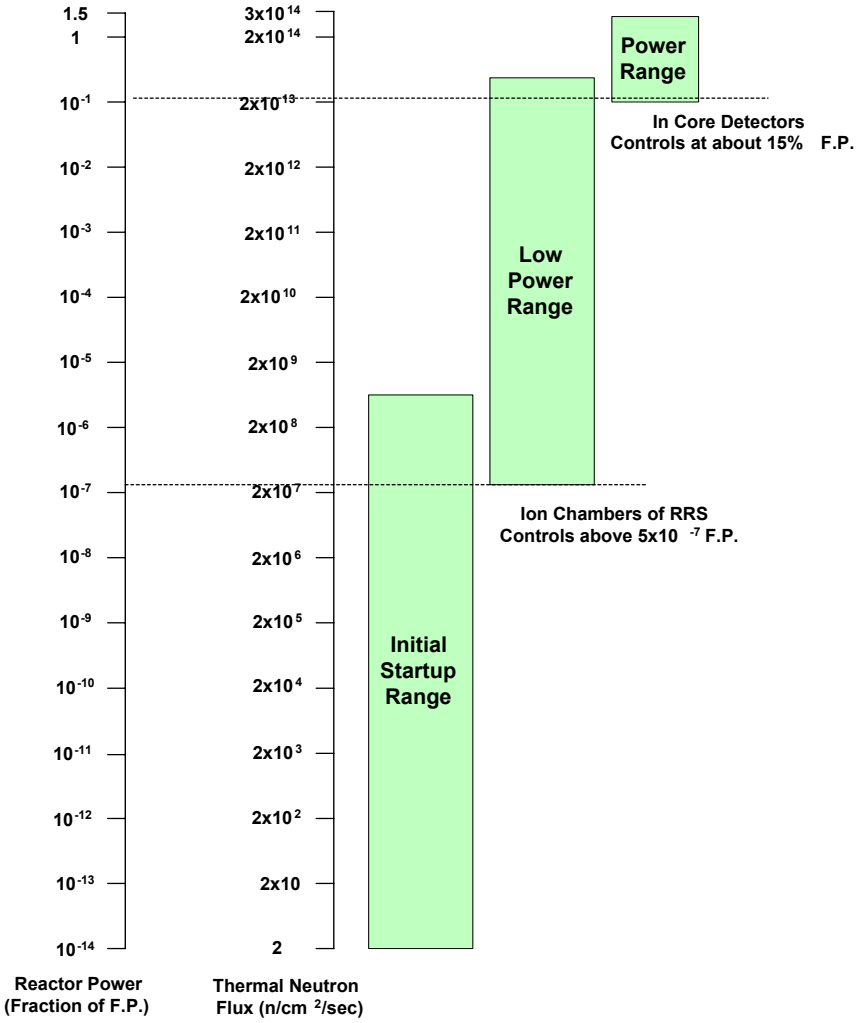
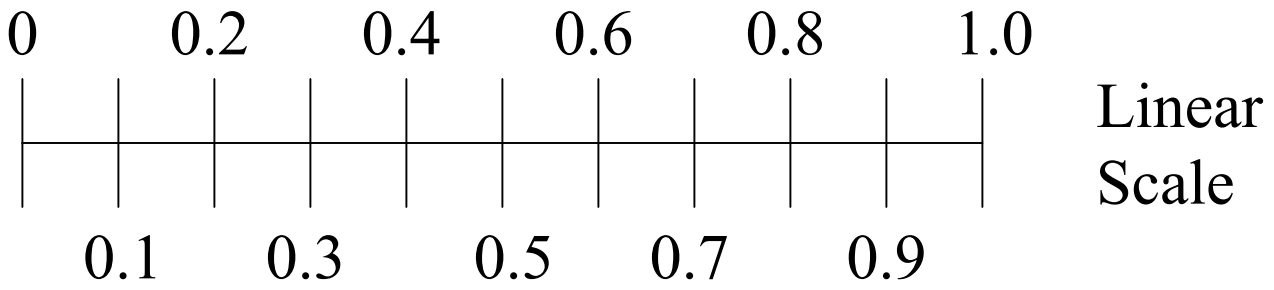
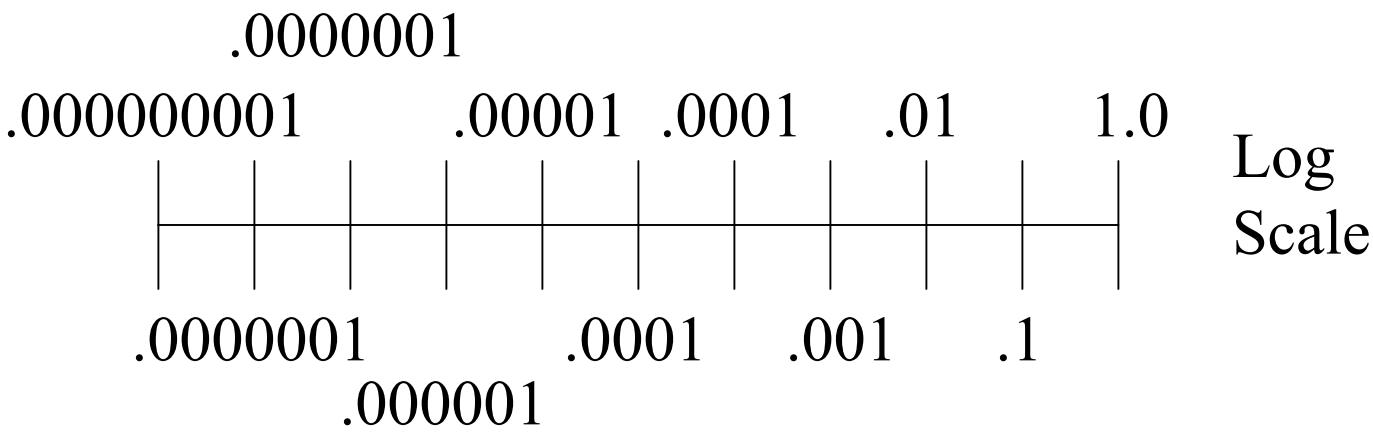
Neutron Flux Measurement

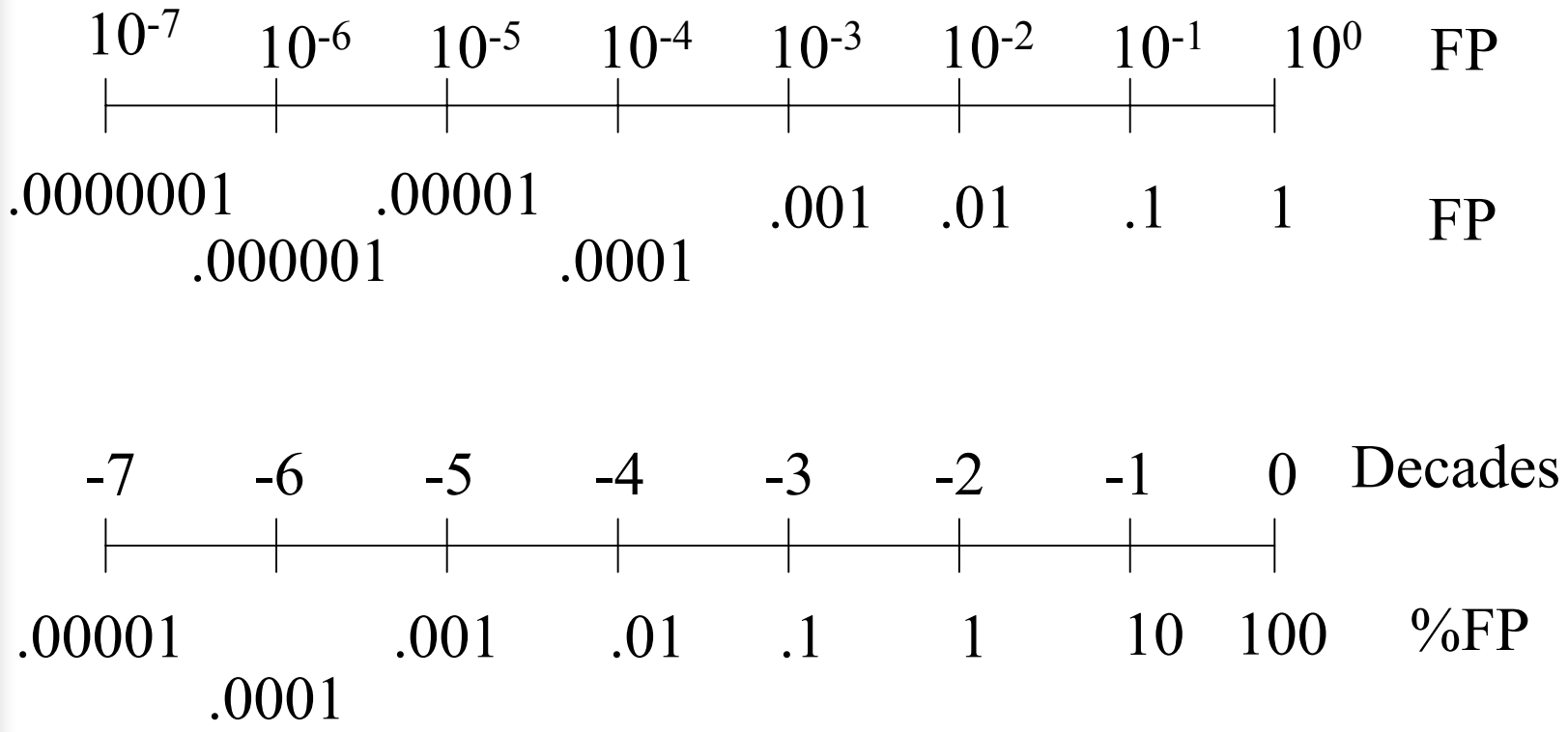

1.5
1
10-1
10-2
10-3
10-4
10-5
10-6
10-7
10-8
10-9
10-10
10-11
10-12
10-13
10-14
Reactor Power
(Fraction of F.P.)
3x10 14
2x10 14
2x10 13
2x10 12
2x10 11
2x10 10
2x10 9
2x10 8
2x10 7
2x10 6
2x10 5
2x10 4
2x10 3
2x10 2
2x10
2
Thermal Neutron
Flux (n/cm 2/sec)
Power
Range
In Core Detectors
Controls at about 15% F.P.
Low
Power
Range
Ion Chambers of RRS
Controls above 5x10 -7 F.P.
Initial
Startup
Range

Log vs. Linear Meters

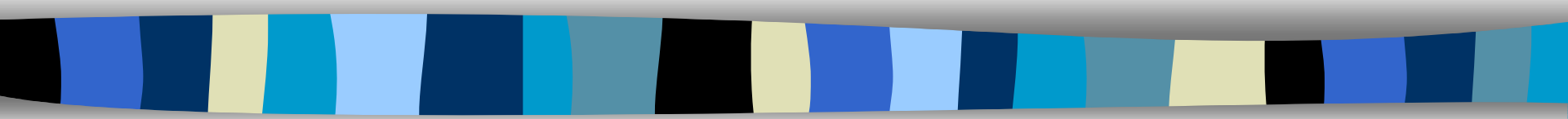




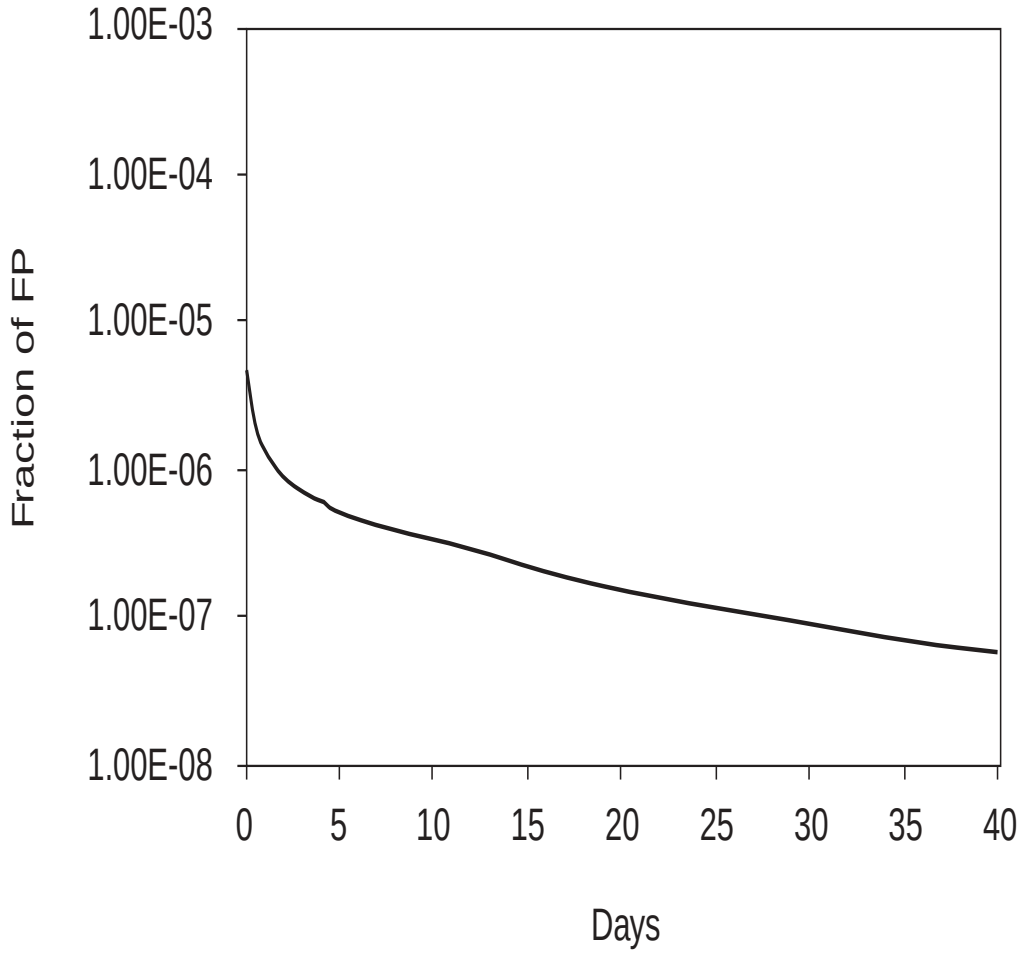
Four Power Scales



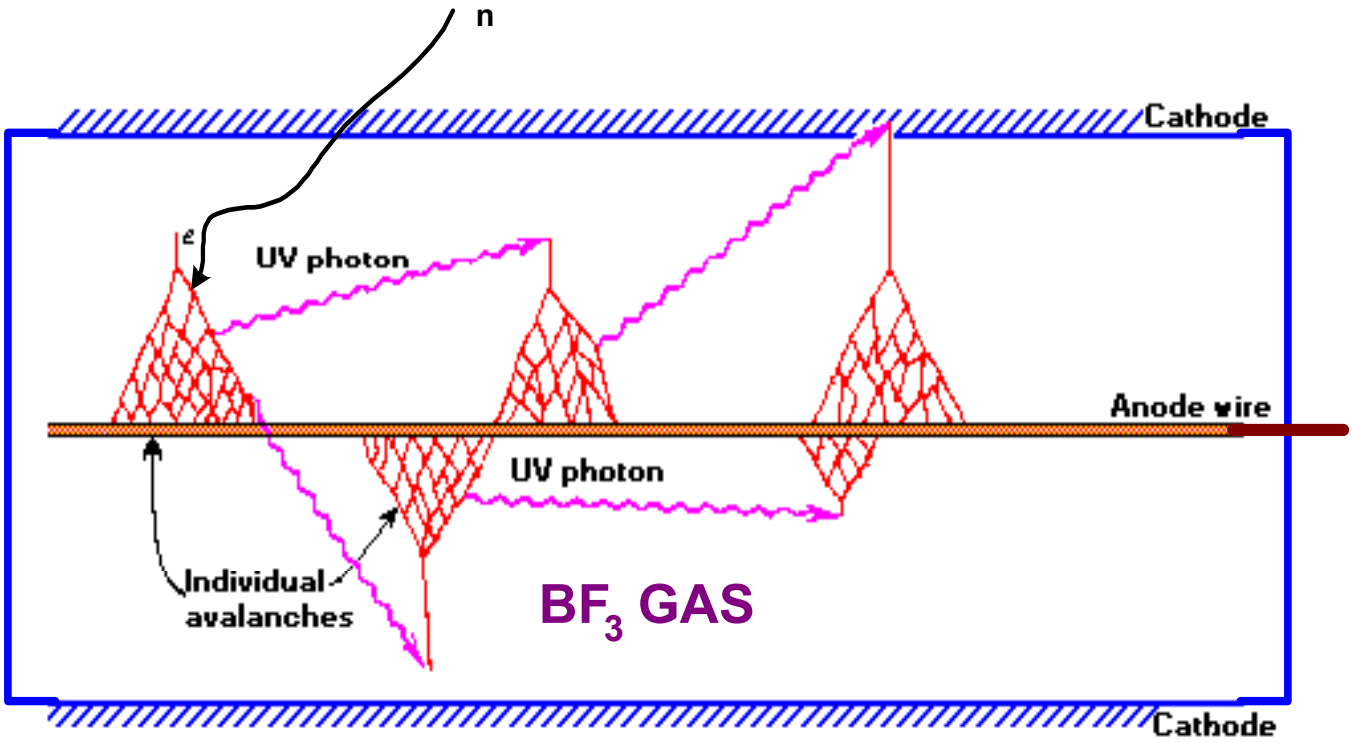
Startup Instrumentation



Reactor Power After Shutdown



Boron Tri-fluoride Detectors



$$n + B10 \rightarrow Li7 + \alpha$$

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

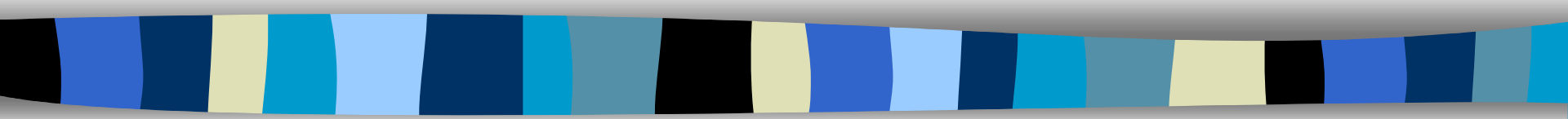
Even More About Start-up Instrumentation

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

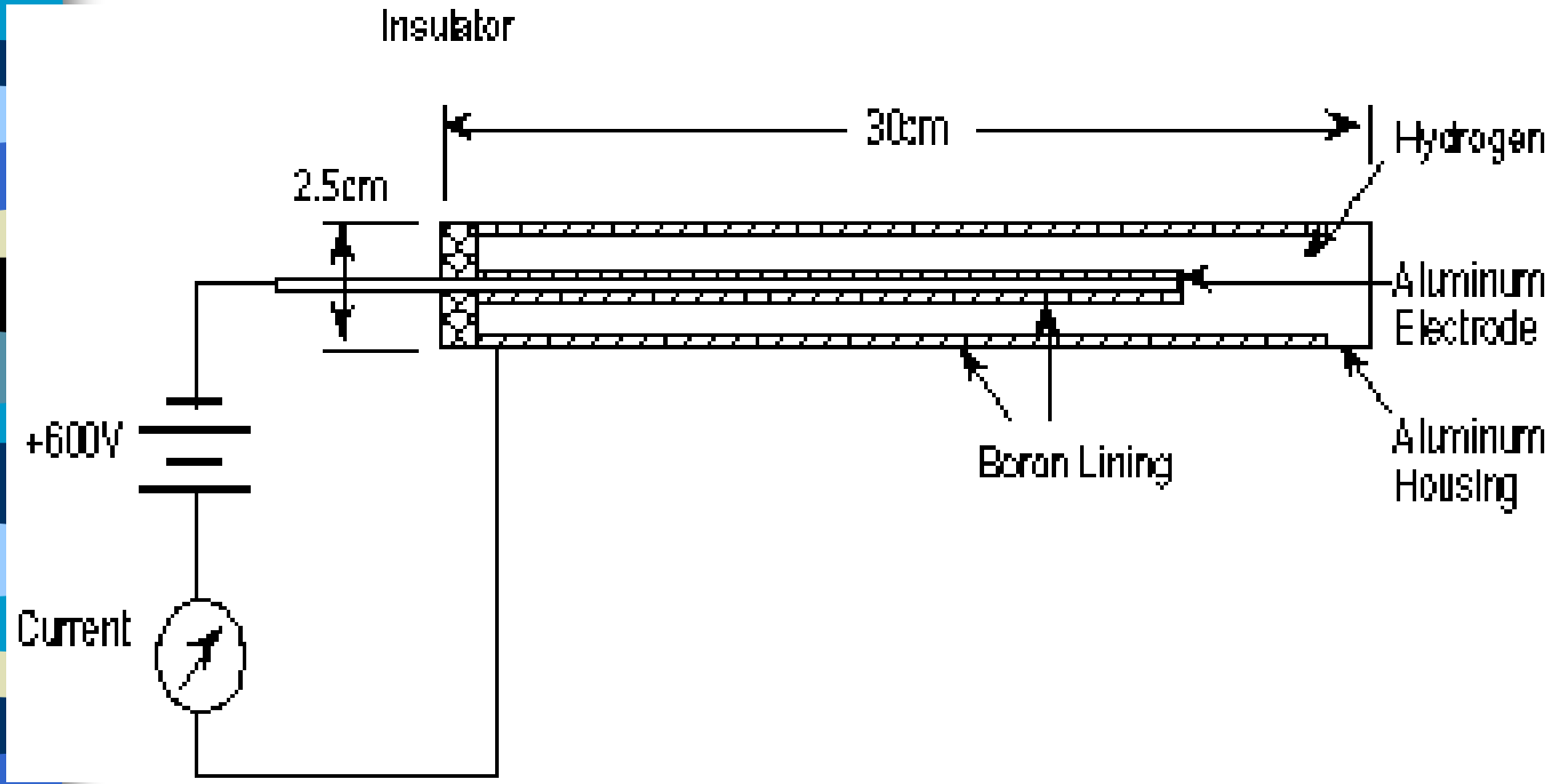
Fission Chambers

- 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

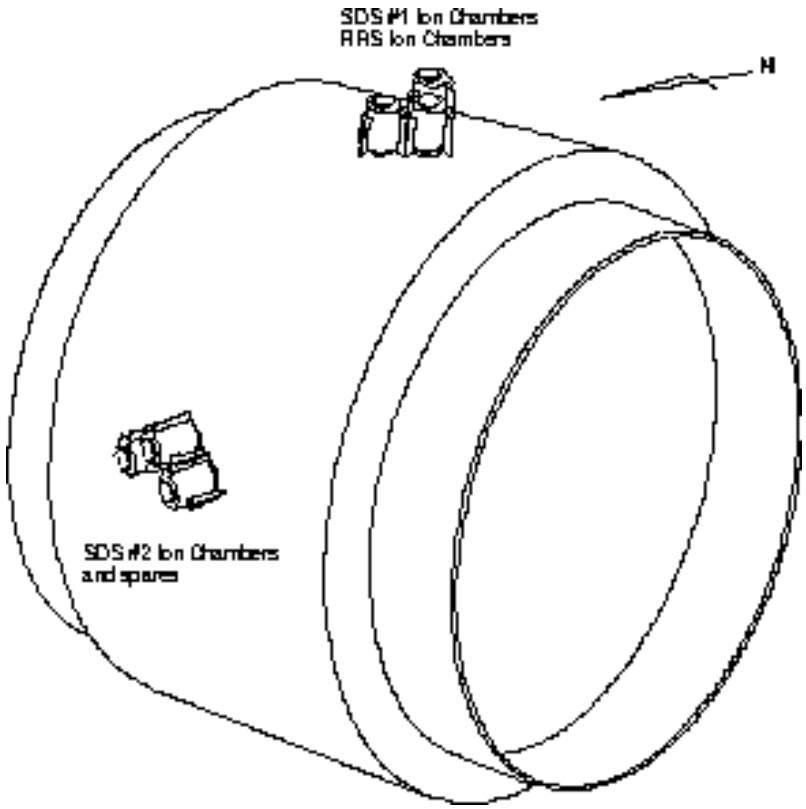
Run up Instrumentation



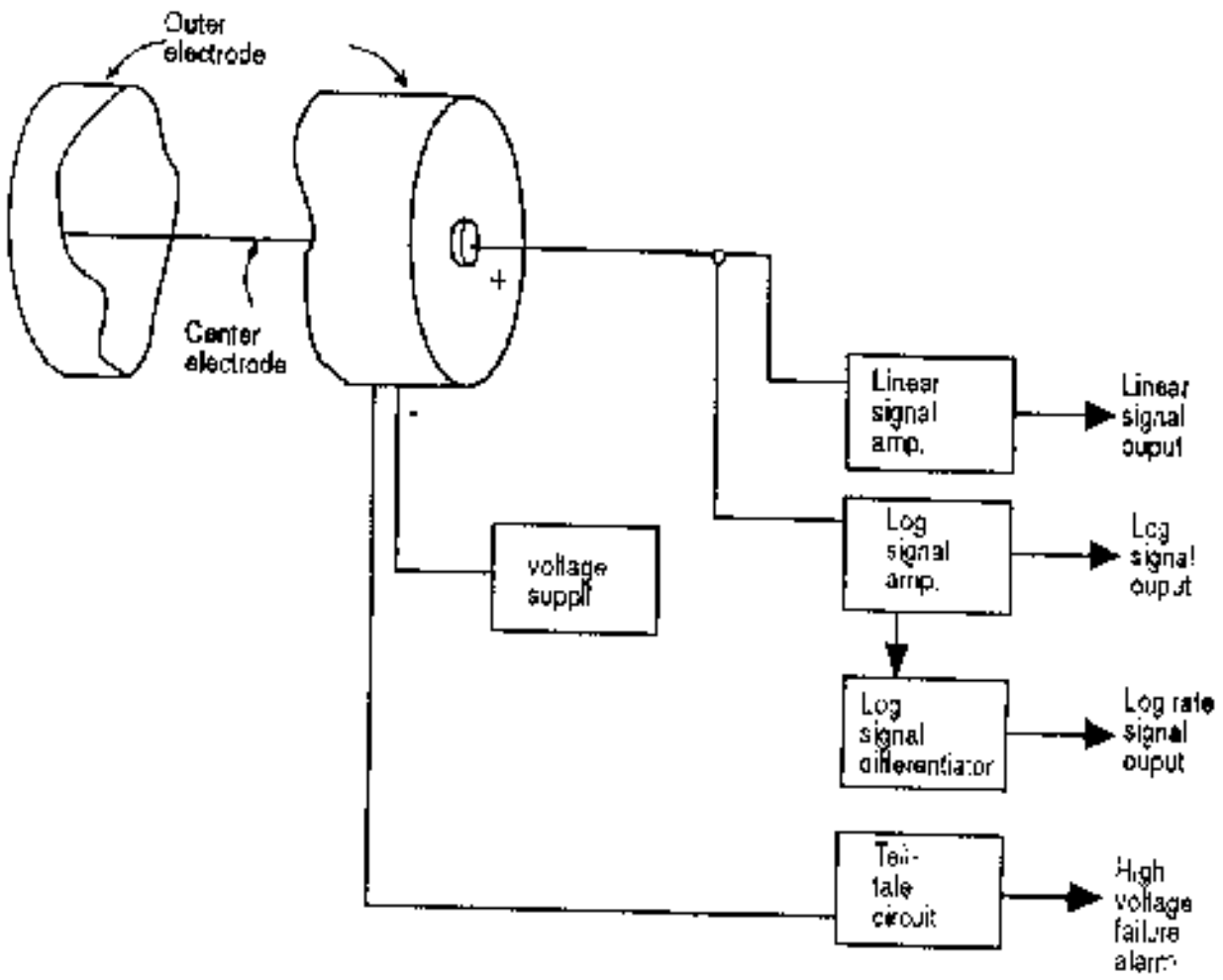
Ion Chambers



Typical Ion Chamber Locations



Ion Chamber Circuits



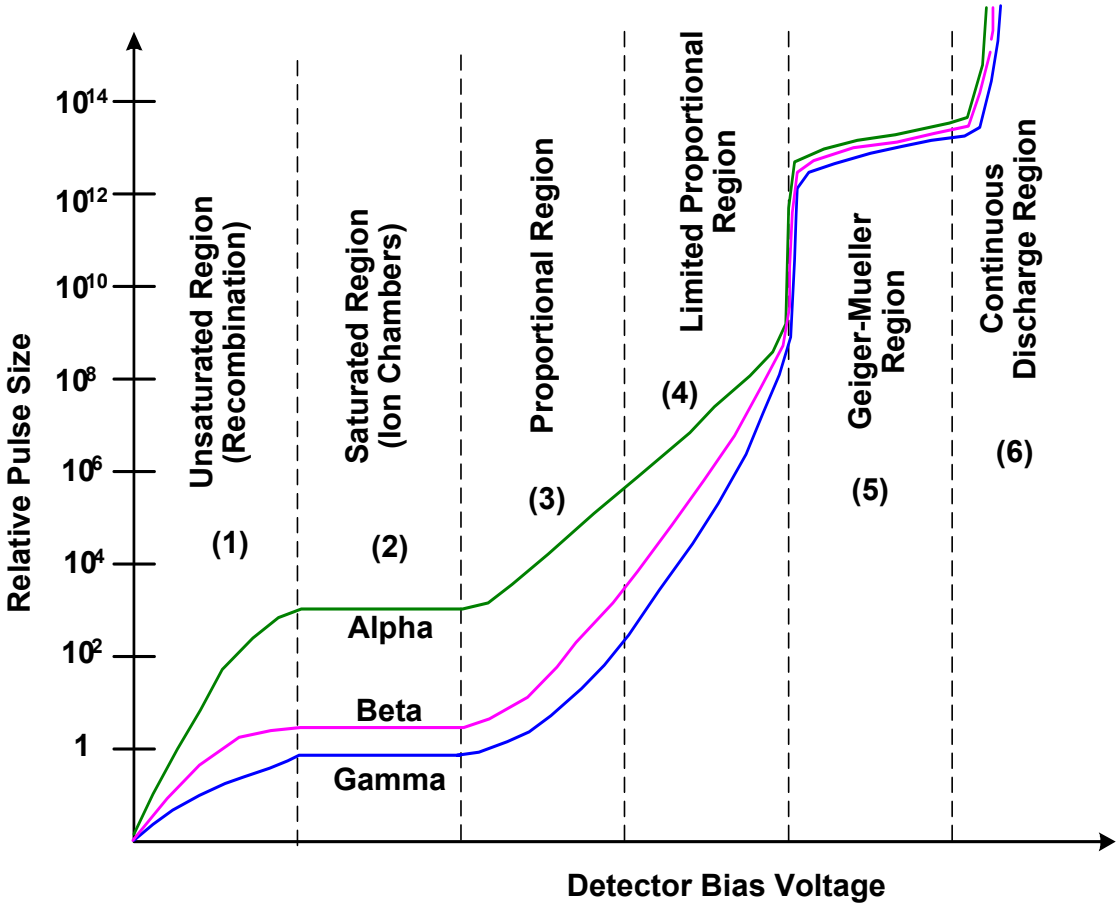
Gamma Discrimination

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

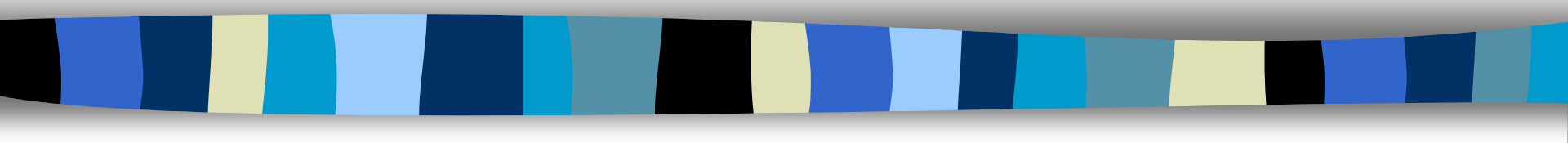
Ion Chamber Accuracy.

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

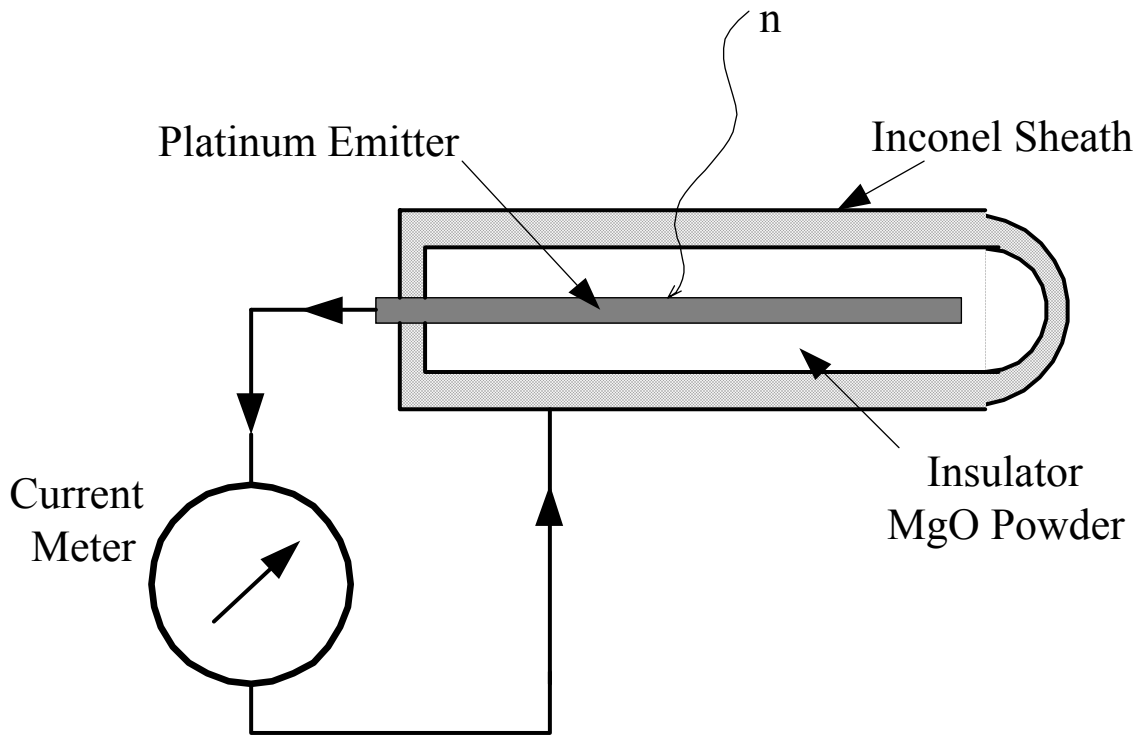
Gas Detector Curves



Under Load Instrumentation



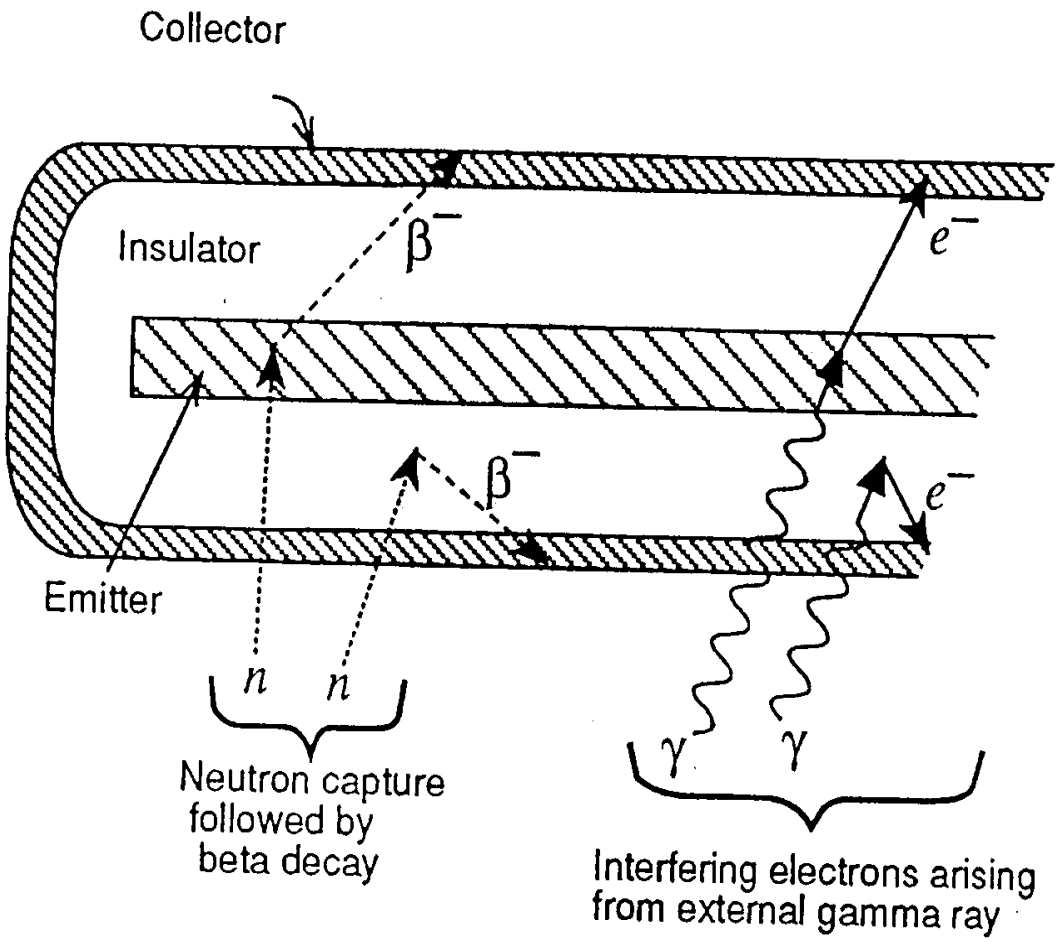
In-Core Detectors



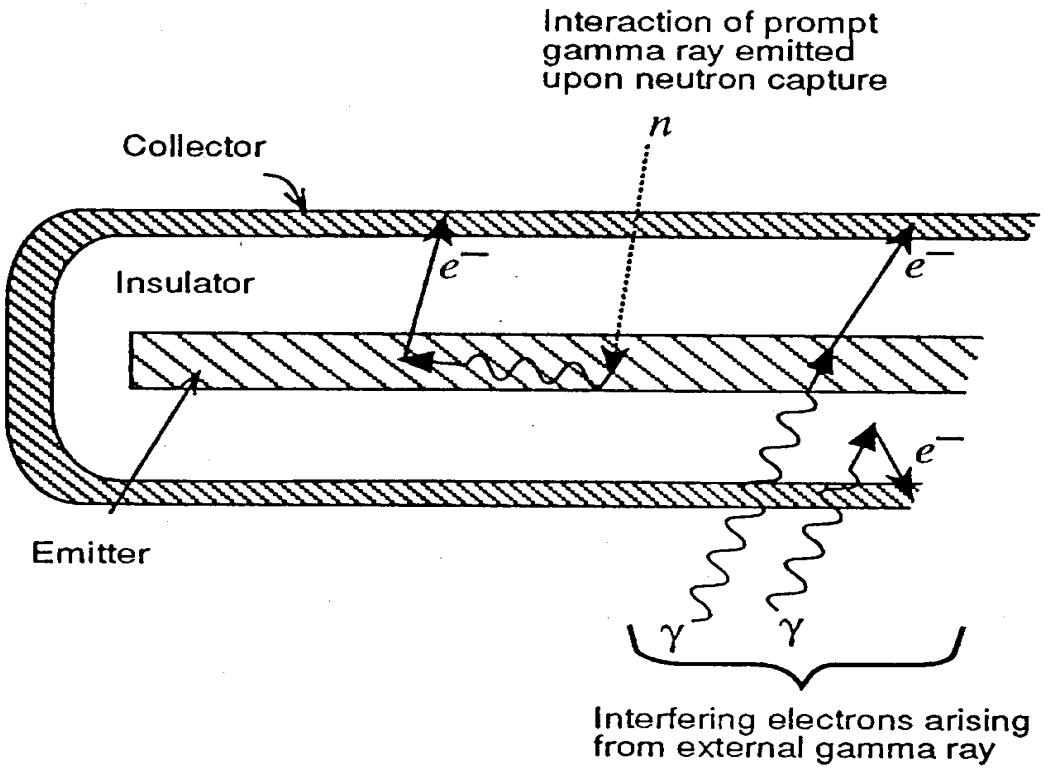
Major Reactions

- 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%

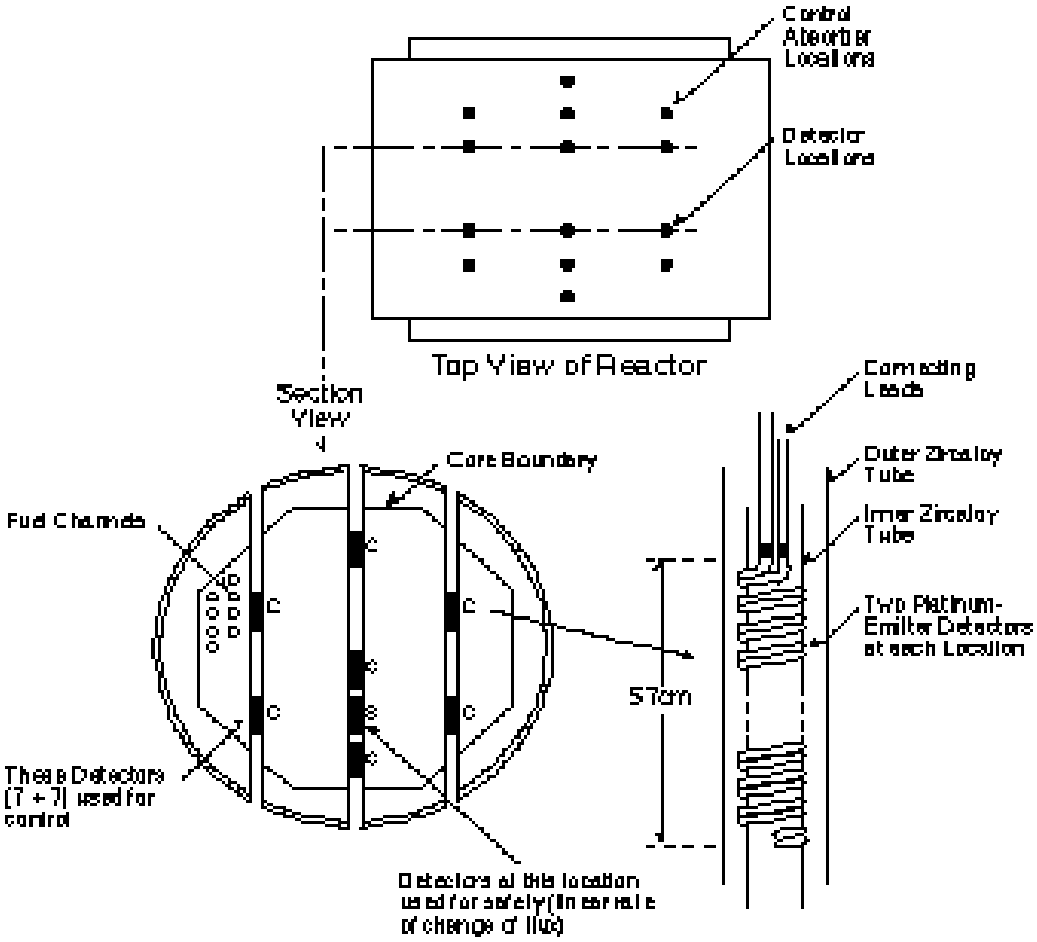
Inconel Detectors

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

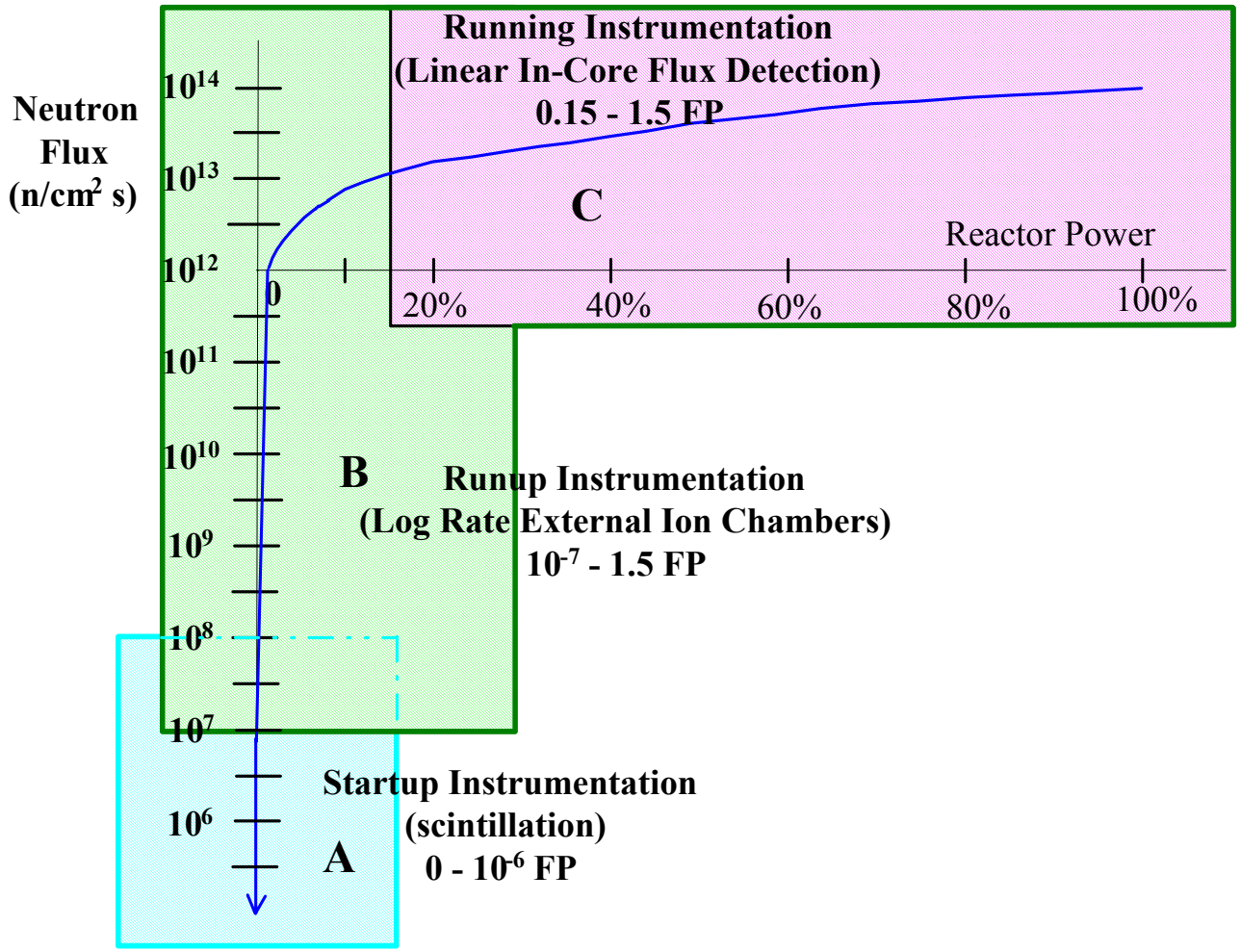
Vanadium

- 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