High Energy Detectors and Telescopes

1. Count photons to determine flux, F (#/cm^2/s)
2. Measure direction of the photons -> intensity, I (#/cm^2/s/sterad)
3. Measure the energy of the photons -> F_nu and I_nu

1. Count photons; flux = rate/(detector area);
maximum for x-ray sources is 4 ph/cm^2/s

- Must measure the collecting area.
- Must calibrate the efficiency of the detector -> "effective area"
- Must reject events that are not due to photons = "background". Charged particles often create rates > photon rates.

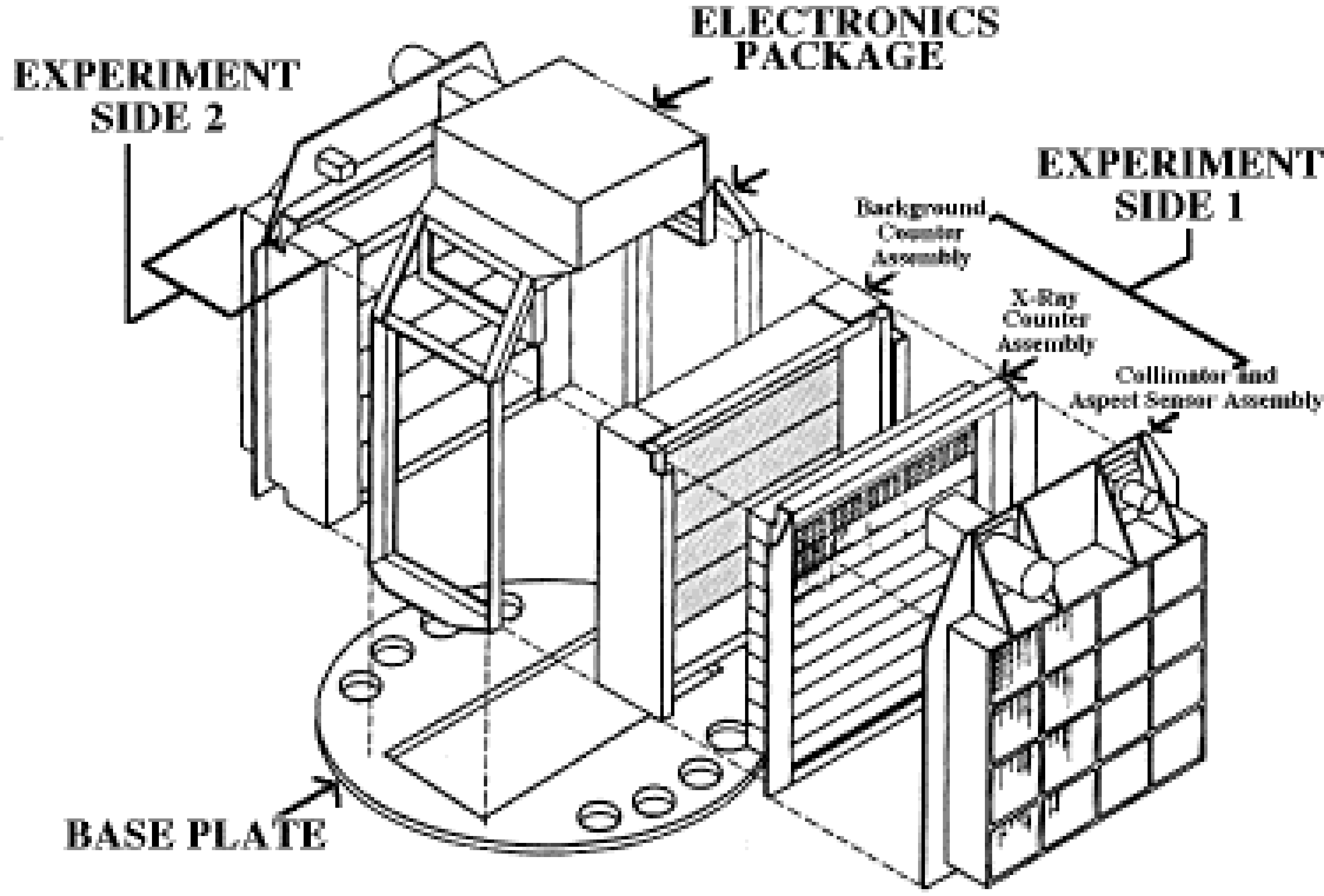
flux = (observed rate – background rate)/area

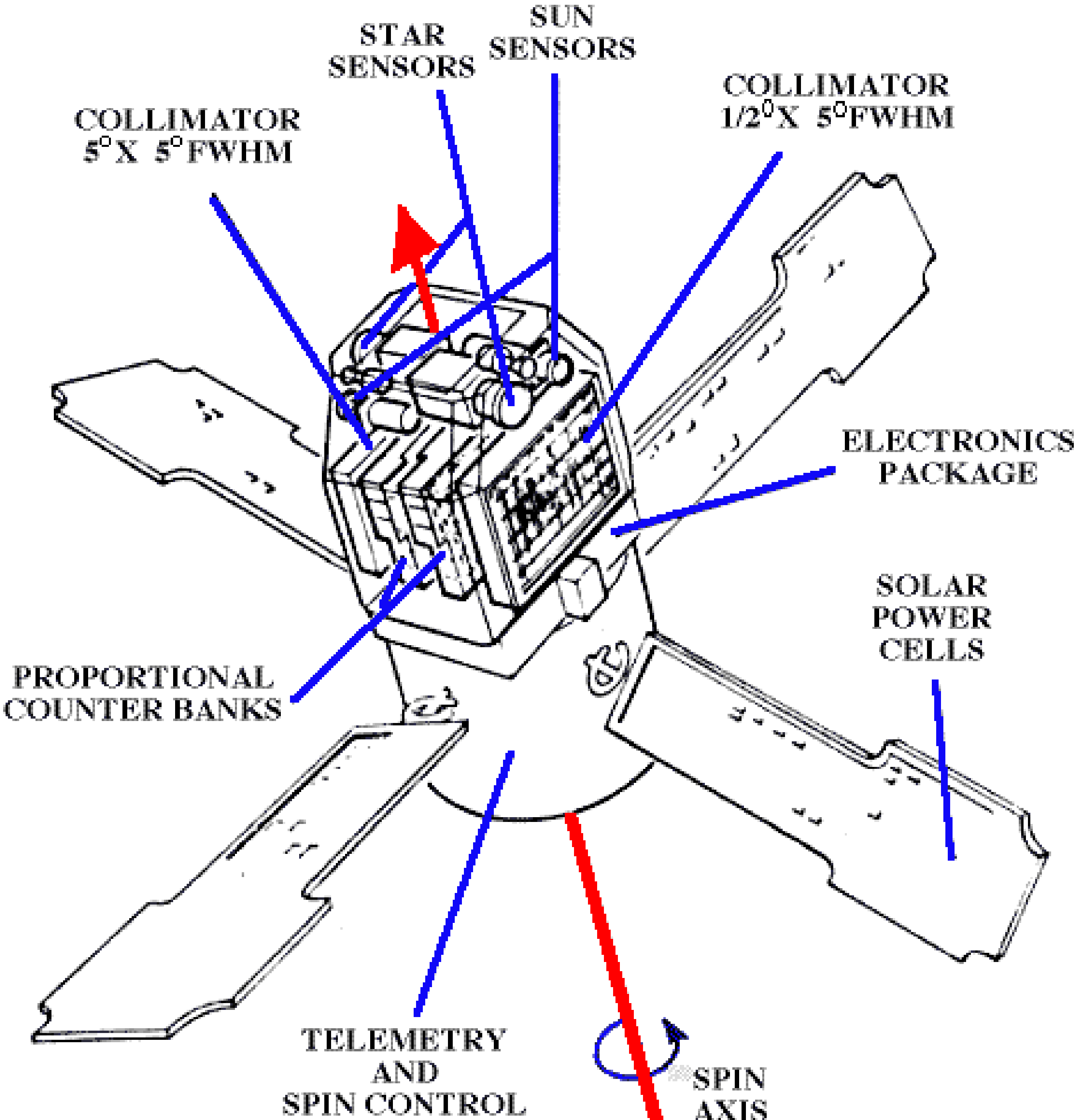
The background rate is usually time-variable.

2. Measure photon direction

- Want to measure the flux from one object or the intensity from points within an object.
- A) restrict the solid angle from which photons can reach the detector (a collimator).
- B) use a device (camera/telescope) that maps photons coming from a direction to a point in the detector and use a detector that can determine where the photon was absorbed (imaging detector).
- Must calibrate the angular efficiency of the system -> angular resolution.

Uhuru collimator and detector (angular resolution = 0.5 & 5 degrees





Uhuru spins to scan the sky

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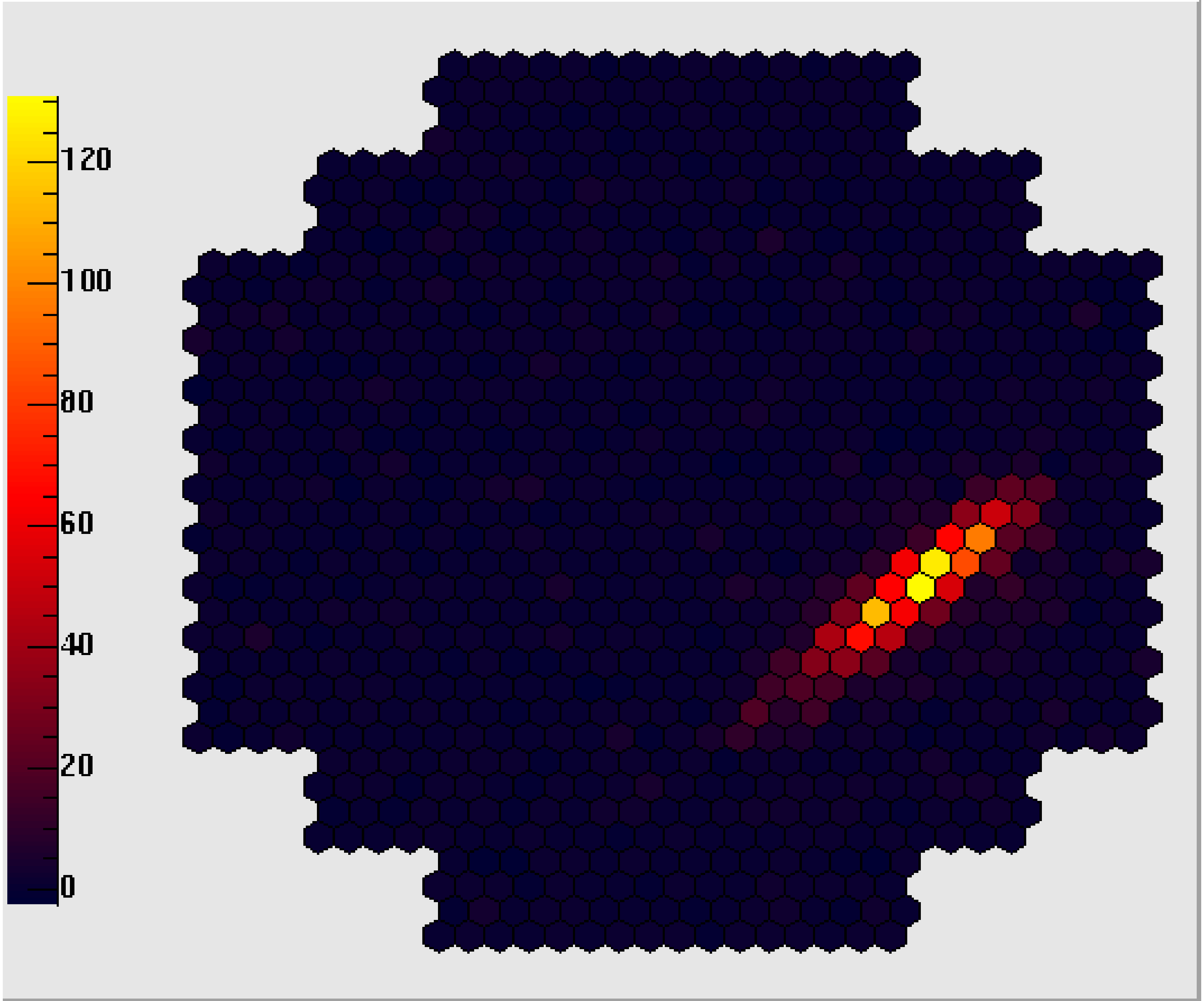
At the highest photon energies can measure the momentum transferred to the detector.

- Direction of the “electromagnetic shower” of particles generated by the absorption.
- Atmospheric Cerenkov detectors (HESS, Veritas, Magic)
- Or detect particles/photons reaching the ground (Milagro and cosmic ray detectors); the direction comes from timing.
- Ultraviolet fluorescence of nitrogen atoms in the atmosphere can also be used to measure the shower (cosmic ray detection).

HESS air cerenkov detector

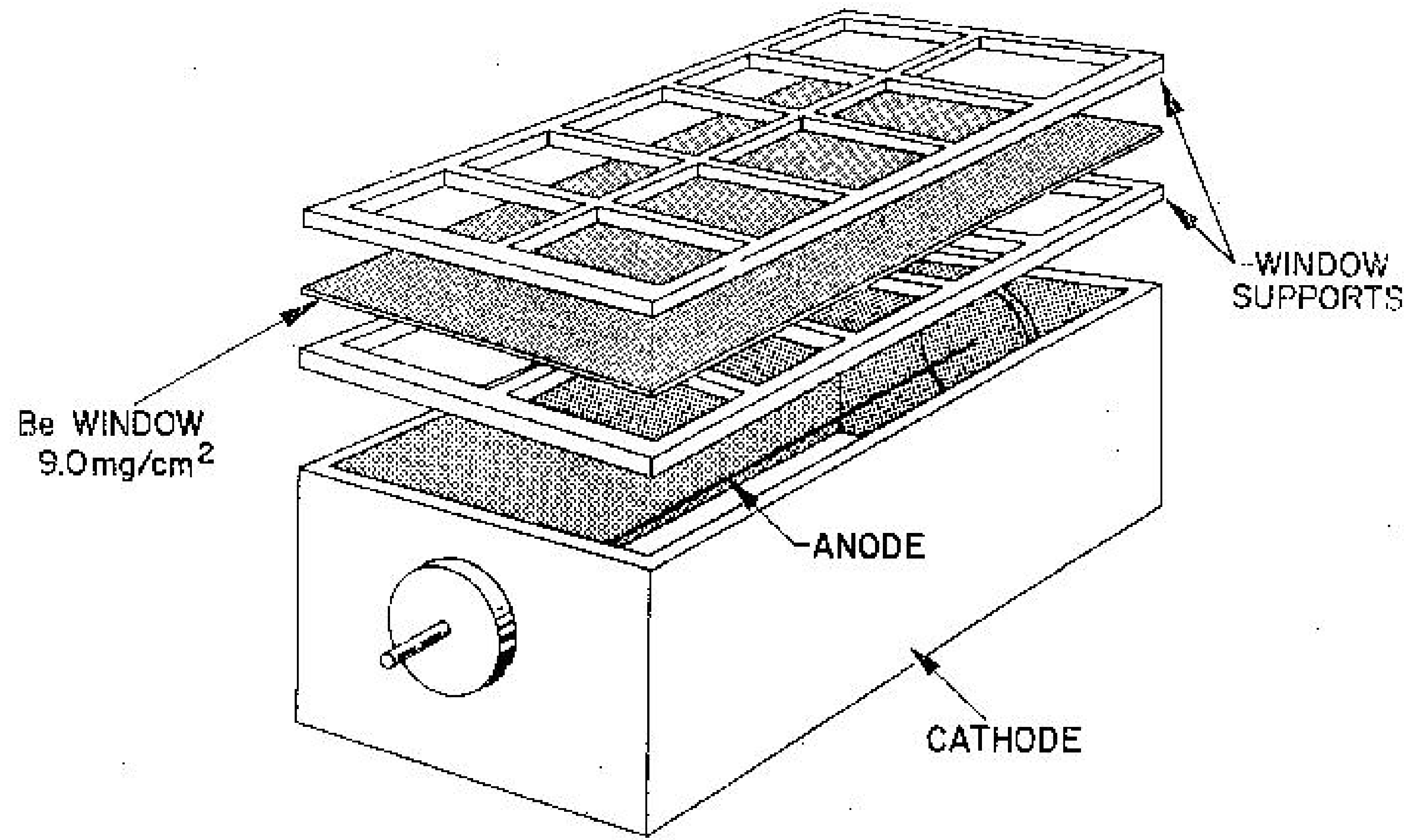

120
100
80
60
40
20
0

3. Measure photon energy

- Distribution in energy (spectrum) contains much information on emission processes and source properties.
- Must calibrate efficiency as a function of energy.
- Accuracy of energy measurement determines “energy resolution”.

What is a Proportional Counter?

- Essential components:
  - Window
    - Defines low-E end of the range of efficient detection
  - Absorption/drift volume
    - Defines high-E end of the range ($\sigma\downarrow$ as E $\uparrow$)
  - Multiplication region
    - High field region near anode
  - Readout
    - Electrodes may (or may not) be multiplication electrodes
- Essential Physics
  - Photo-electric cross section



Be WINDOW
9.0mg/cm^2
WINDOW
SUPPORTS
ANODE
CATHODE

Proportional Counter Details

- Quench gas: eliminates secondary avalanches.
- Dead time: positive ions created by the avalanche cause brief insensitive interval
- Time resolution: determined by the time for charge to drift to anode − typically microseconds
- Energy range: The window determines low-E cutoff in efficiency. Dropping cross-section determines high-E boundary. Typical range is 20-50 keV.
- Energy resolution: set by variations in initial production of electrons and avalanche gain. Typically 10 – 20%

Proportional counter: background suppression

- Partition detector: add a guard counter that is not sensitive to photons. Can reduce background by 100 times.
- Rise-time discrimination. Can reduce background by 30 times.
- Pulse-height discrimination. Can reduce background by 100 times.