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IVC. Analyzers

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Terminology

Pass Energy E_P

The energy of the electrons as they pass through the analyzer.

Transmission Function $T(E)$

How well the analyzer transmits a given input signal at a given energy.

Resolution

> **Absolute Resolution** ΔE
>
> The energy spread induced by the analyzer as an electron passes through it.
>
> **Relative Resolution** $\Delta E/E$
>
> The energy spread at a given energy.

Goals

The ideal electron analyzer should have

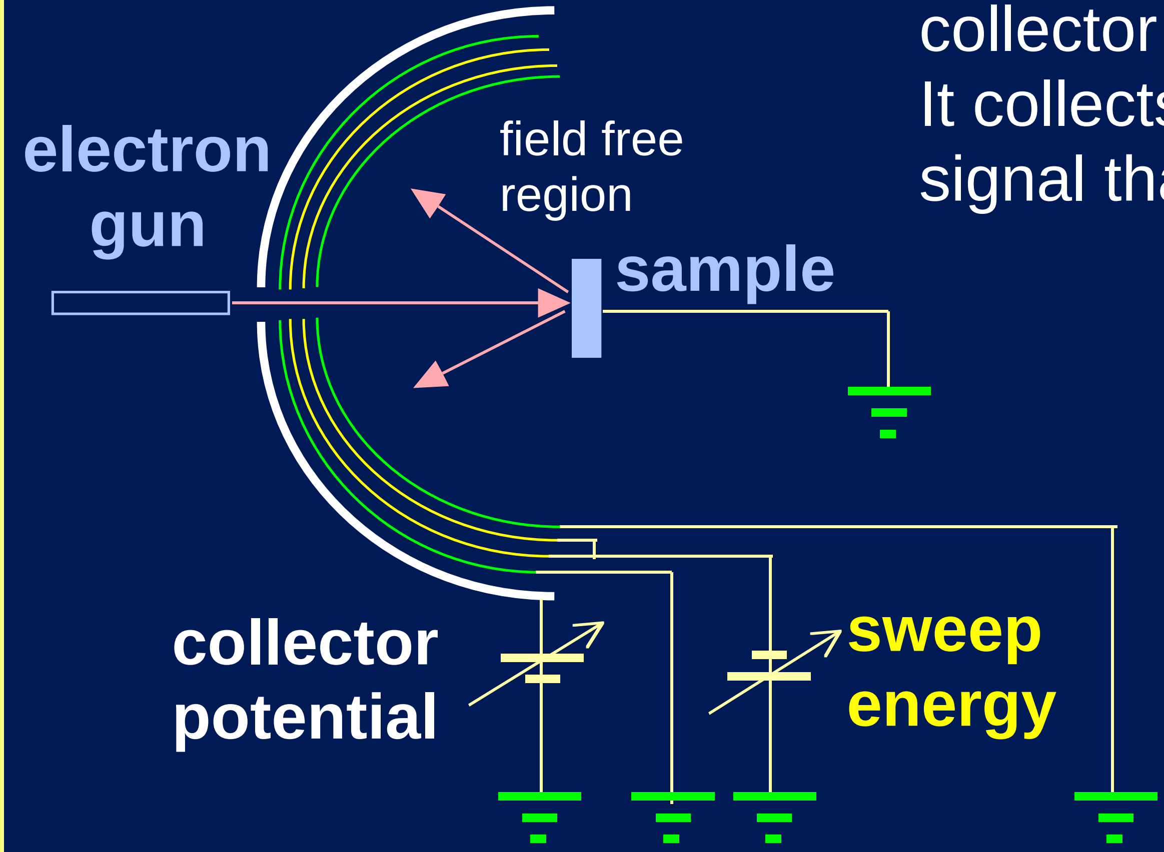
- an infintesimly small analysis energy window (zero energy spread due to the analyzer)
- transmission of all electrons from the event in the spatial region of interest (a high transmission function)
- a transmission function that is independent of pass energy
- resolution that is independent of pass energy
- in some cases, spatially focussed analysis at the sample (small spot capabilities)

Limitations

Electron analyzers use electrostatic or electro-magnetic fields to deflect electrons. Because the fields can only be controlled to finite precision, the entrance and exit slits have finite width, and the field regions between analyzer components have abrupt discontinuites, we find that

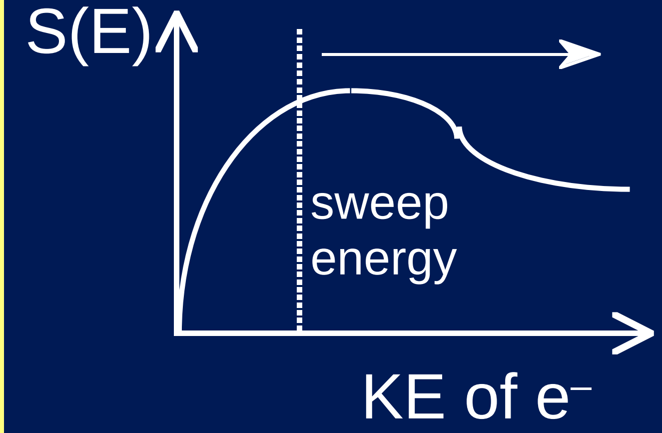
> all analyzers cause some energy spread in transmitting the signal through to the detector
>
> all analyzers have losses of signal that vary with pass energy

Retarding Field (RFA)



The hemispherical collector is the detector. It collects all of the signal that reaches it.

Operation Principles



All electrons with a KE greater than the sweep energy get past the inner grids and reach the detector.

The signal measured at the detector, I(E), is an integral of everything greater than the sweep energy.

$$I(E) = \int_{E_{\text{sweep}}}^{\text{infinity}} S(E)\, dE$$

In order to obtain the signal from the event, S(E), we have to differentiate the measured signal, I(E).

Pros and Cons

Pros

High collection efficiency.

Easily constructed and maintained.

Can be integrated with low energy electron diffraction (LEED).

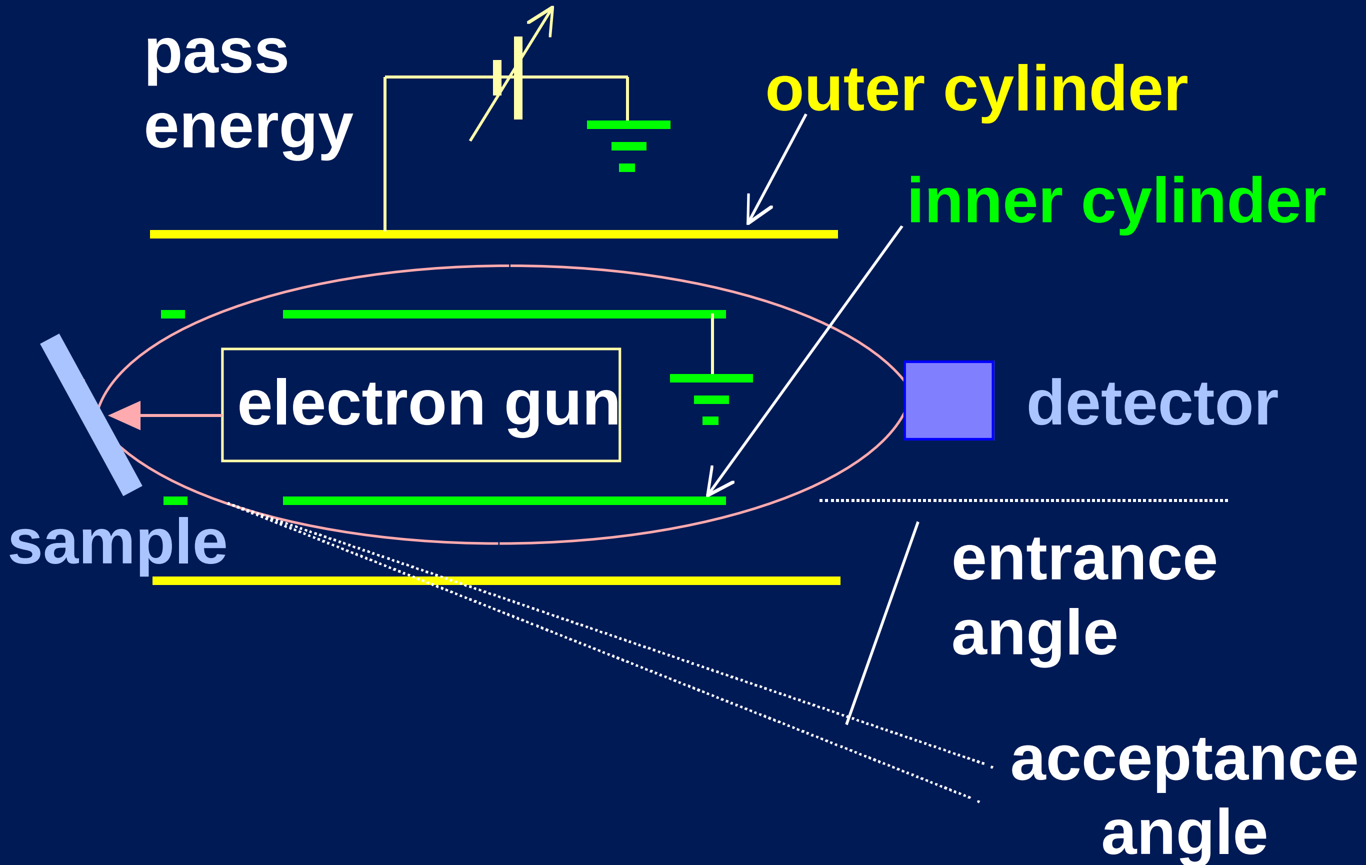
Cons

Poor signal to noise.

Requires differentiation (smoothing operation) of measured signal to obtain S(E).

No spatial selection of signal from sample without complex mechanical aperture design.

Cylindrical Mirror (CMA)



Operation Principles

Electrons enter the analzer at the entrance angle, α, through an entrance slit.

They are deflected by the (negative) potential on the outer cylinder.

Only those electrons at the pass energy, E_p, reach the exit slits. This is called focusing.

Electrons with energies of $E_p \pm \Delta E$ will also be focussed by the analyzer if they arrive at at the entrance slit at angles $\alpha \pm \Delta\alpha$ (acceptance angle). The energy spread in the transmitted signal is dependent on slit width and acceptance angle.

Pros and Cons

Pros

High collection efficiency.

Easily constructed and maintained.

Can be made compact in size.

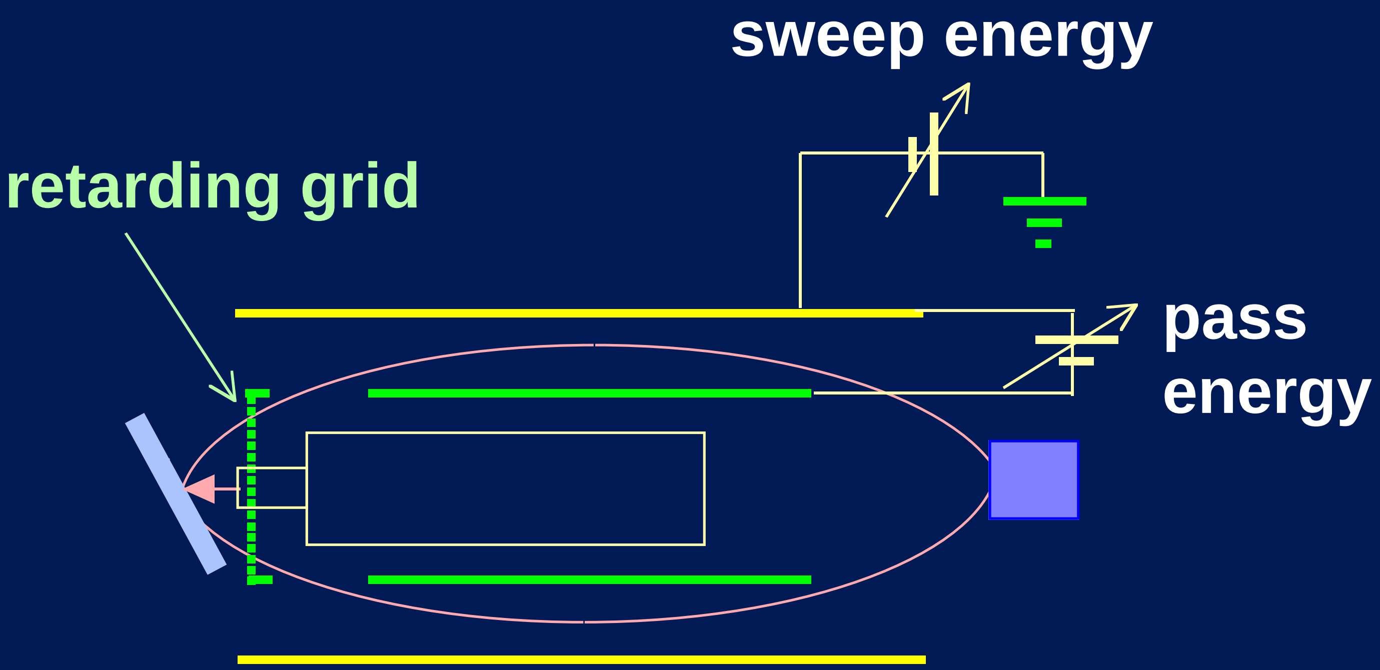
Cons

Energy calibration depends on sample position in front of analyzer.

Resolution depends on E_p and size of analyzer.

No spatial selection of signal from sample without complex mechanical apertures in analyzer.

Advanced CMA

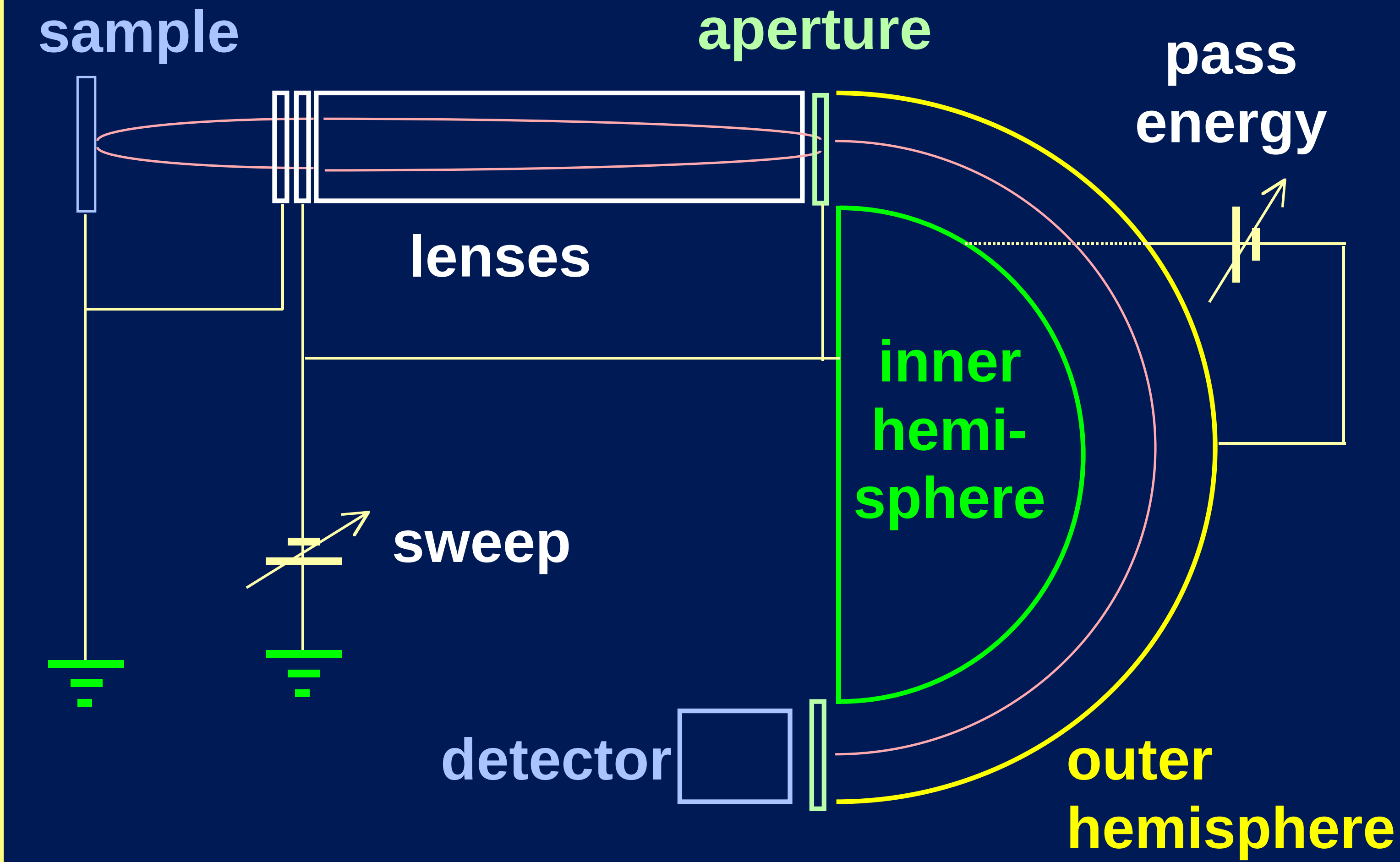


Advantages

The retarding grid slows down the incoming electrons to one given value of E_p regardless of their initial KE.

The absolute resolution ΔE is therefore independent of initial KE.

Hemispherical Sector (HSA)



Operation Principles

Electrons with an energy greater than the sweep energy enter the lenses at the entrance angle, α.

They are focussed through the lenses onto the entrance slit of the analyzer.

Only those electrons at the pass energy, E_p, reach the exit slits of the analyzer.

Electrons with energies of $E_p \pm \Delta E$ will also be focussed by the analyzer if they arrive at at the entrance slit at angles $\alpha \pm \Delta\alpha$ (acceptance angle). The energy spread in the transmitted signal is dependent on slit width and acceptance angle.

Pros and Cons

Pros

Can be designed with lenses to increase working distance to sample and to provide spatial focussing at the sample.

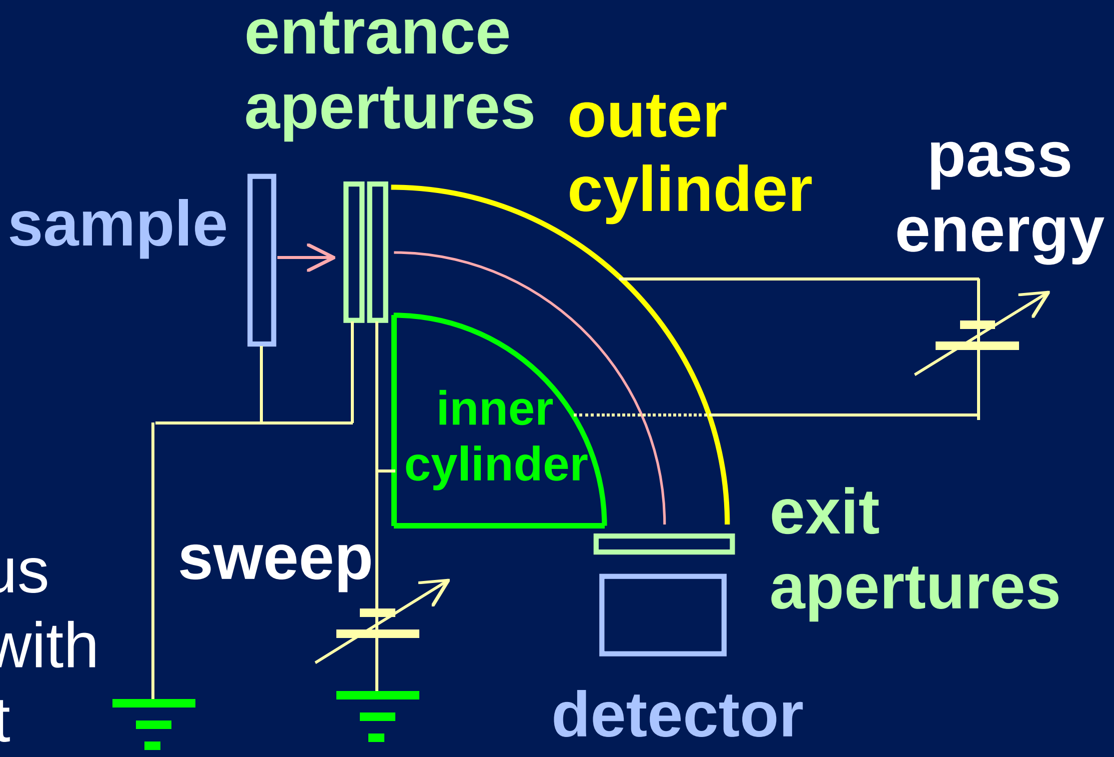
Cons

Resolution depends on E_p and size of analyzer.

Cylindrical Sector (CSA)

The operation principles are similar to those for the HSA.

Optimal focus is obtained with a sector that has an arc length of 72^o.



Pros and Cons

Pros

Can be designed to provide very high resolution (very low ΔE) in transmitted signal.

Can be used for angular studies.

Cons

Resolution depends on E_p and size of analyzer.

Short working distance between sample and entrance apertures.

Comparisons

	CMA	**HSA**
E_p	$1.3099\ \Delta V / \ln(r_o/r_i)$	$\Delta V / (r_o/r_i - r_i/r_o)$
Relative Input	$2 \sin(\alpha)\ \delta\alpha$	$(1 - \theta)^*$
	$\alpha \sim 42^o$, $\delta\alpha < 6^o$	$\alpha \sim 10\text{–}20^o$

r_o - major (outer) radius r_i - minor (inner) radius

ΔV - voltage between outer and inner radius

α - analyzer input angle $\delta\alpha$ - half angle of spread in α

θ - half angle of input to lens

* - when lens aperture controls input